TABLE OF CONTENTS

SECTION I - BASIC DESCRIPTION

A. ***<u>Geographical Location</u>***

1. Moffett Federal Airfield is located at latitude 37 deg 25'N, longitude 122 deg 03'W. The field is 27 nautical miles southeast of San Francisco International Airport and 6 nautical miles northwest of San Jose International Airport. The field elevation is 34 feet above mean sea level. The station covers 1,890 acres of relatively flat land in the lower Santa Clara Valley. It is bordered on the northern perimeter by the marshy extremities of the southern end of the San Francisco Bay, on the southeastern perimeter by the Sunnyvale facility of Lockheed Missile and Space Company, Inc., and on the southwestern perimeter by Highway 101 and the Ames Research Center of NASA.

2. The most distinctive features of the station are the three large dirigible hangers. Hangar No. 1 is located on the west side of the runways, and Hangers No. 2 and 3 are directly opposite on the east side of the runways. The hangars are approximately 1,100 feet long and from 190 to 200 feet in height. The two parallel runways, 600 feet apart, centerline to centerline, are oriented northwest to southeast. Runway 14R/32L is 8120 feet X 200 feet (asphalt with concrete). Runway 32L has a displaced landing threshold of 607 feet due to the proximity of Highway 101. Runway 14L/32R is 9200 feet X 200 feet (concrete).

3. The buildings west of Hangar No. 1 comprise the air field and other government facilities. All taxiways and parking areas around the hangars and adjacent to the runways are paved concrete.

4. The NAVAIRRES Santa Clara Weather Office is located in the Air Traffic Control Tower (ATCT) building 158.

B. ***<u>NAVAIRRES Santa Clara Weather Office Spaces</u>***

1. NAVAIRRES Santa Clara Weather Office has been allocated approximately 540 square feet of working space in the ATCT in rooms 115 and 121. Additionally, room 101 has been allocated as an administrative office for the NMORA 1887, which has approximately 255 square feet of working space. Over-the-counter and telephone weather briefs are conducted in the Forecast Duty Officer (FDO) space in room 115. The facsimile data, satellite imagery and teletype data necessary for comprehensive briefings are displayed in this space, as well as the equipment used to display ASOS weather observations from the field.

C. ***<u>Meteorological Instruments and Exposures</u>***

1. NAVAIRES Santa Clara weather office instruments consist of an ASOS at the approach end of runway 32L. The ASOS has display terminals in the approach control room of the ATCT, the FDO space and the flight ops spaces for NASA. The ASOS displays cloud height and amount, visibility (including present weather restrictions to visibility), wind direction and

speed, temperature, dewpoint, relative humidity, sea level pressure, altimeter setting, pressure altitude and density altitude. The air traffic controllers have the responsibility to amend the ASOS transmission during field operating hours (0630L - 2230L) to include changes to, or addition of, information and remarks regarding cloud amount (the ASOS has a very narrow field of view, i.e. - no peripheral vision), thunderstorm information (during non-field hours the ASOS transmission will be automatically suffixed with the remark "TSNO"), and prevailing visibility remarks or corrections (the ASOS transmissometer measures the visibility at a single point where the sensors are located).

2. There is an aneroid barometer, a sling psychrometer and a hand-held anemometer kept in the FDO space to use as an alternate source of data in the event of a power outage or ASOS failure. In the event of an ASOS failure, the trouble call is automatically made to the National Weather Service technician.

D. *Communications and Meteorological Support Equipment*

1. The NAVAIRES Santa Clara Weather Office uses a variety of communications equipment in its routine forecasting functions.

a. A 75 MHz Pentium computer is used in room 115 of the FDO space as a dedicated system for displaying DIFAX charts only. The DIFAX data is stored and managed by a software program supplied by Marta Systems, Inc., the Super-86 or PCGRAFAX Program. The DIFAX charts are received via a microwave dish antenna on the roof of building 158. The DIFAX signal is routed to the FDO space by a cable, which drops down from the roof and passes through the window frame of room 115. The cable is connected to an Equatorial controller, which is connected to the computer.

b. A 75 MHz Pentium computer is used in room 121 of the FDO space to run OPARS, NODDS, the internet access, and also word processing and administrative functions. Internet access is gained through an Ether-link card in the computer, which is connected, to the NASA ARCLAN terminal in room 115. The Internet is the primary source of satellite imagery, with NODDS as a backup.

c. The Contel Meteorological Workstation (CMW) is in room 115. The VSAT antenna for the CMW is located on the opposite side of the airfield, next to building 301, where the indoor unit is located. The signal from the indoor unit is transmitted via dedicated 9600 baud modems on each end of the circuit. The contract for the CMW is scheduled to expire in July 1998, and will be replaced by the system known as MIST, which is being provided by the Air Force (located in this office, but it will be the property of the Air National Guard 129th SAR Squadron). The MIST will be a dedicated Pentium computer which will be connected to the ARCLAN, and will be in room 115.

d. A Metro Frequency operated on 341.3 MHz is also in use in room 115. This is used for in-flight weather brief updates and for pilot reports.

E. *Commands/Staffs Supported*

1. NAVAIRES Santa Clara Weather Office supports all of the local Moffett Field squadrons, including VR-55, VP-91, the Air National Guard 129th Search and Rescue, the Army Guardrail RC-12's, the NAVAIRES Santa Clara UC-12, all NASA flight ops and also the Coast Guard at San Francisco. NAVAIRES Santa Clara Weather Office also supports all visiting transient aircraft and VIP's, including Air Force One.

2. NAVAIRES Santa Clara Weather Office also supports the Ames Moffett Consolidated Emergency Operations Center by providing tailored data requirements from the CMW to include seismic activity reports, and also Flash Flood and Destructive Winds reports and forecasts.

F. *Manner of Support*

1. Flight weather briefings, in accordance with NAVAIRES Santa Clara Instruction 3710.1, are conducted at NAVAIRRES Santa Clara Weather Office by telephone and over-the counter.

2. Terminal Area Forecasts (TAFs) for Moffett FAF are prepared and transmitted on the CMW for the 1500Z and 2100Z forecasts.

3. Weather warning recommendations will be made by the NAVAIRRES Santa Clara Weather Office FDO to the FDO at NAVPACMETOCFAC San Diego, when conditions are anticipated to meet the appropriate criteria. These weather warnings are issued for the San Francisco Bay area, not Moffett FAF specifically.

4. HWD packets are prepared by the NAVAIRRES Santa Clara weather office FDO in accordance with NAVAIRES Santa Clara Instruction 3710.1. Packets are furnished for flights when requested.

5. OPARS are furnished upon request to flight crews. OPARS are prepared and issued over-the-counter or by telephone (fax).

6. The NAVAIRRES Santa Clara Weather Office also provides climatological data to all local area activities and Department of Defense commands upon request. The majority of the data supplied is used for research studies or pre-deployment briefings.

SECTION II - CLIMATOLOGY

A. General

Moffett Field is located within a meso-thermal climatic zone, more commonly referred to as a Mediterranean or dry summer subtropical type. This climate is primarily characterized by a moderate amount of precipitation in winter and a relatively dry summer. The area is situated in the latitude of prevailing westerlies and on the eastern periphery of the semi-permanent pacific anticyclone. The general atmospheric circulation is characterized by a cool, moist layer of air in the surface strata resulting from the proximity of the bay, and a warm dry layer of air immediately above the surface strata. These conditions cause an inversion to persist near the surface. This subsidence inversion is a contributing factor in producing stratus clouds and fog, and limiting the range of temperatures. The climate of Northern California has two distinct seasons: the rainy winter season (October through March), and the dry summer season (April through September). During the rainy season the primary hazards to aviation are the migratory North Pacific storms and their associated frontal systems; in the summer season it is the fog and low stratus along the coast and in the coastal valleys. Flying weather is generally good in the Sacramento and San Joaquin Valleys throughout the summer.

The rugged terrain of California causes widely varying local conditions. Sectional topographical charts for Northern California clearly show the many mountain ranges and valleys (figure II-1). The coast range is not one single range, but is broken up into several minor ranges. All along the coast are small coastal plains or pockets, such as Crescent City, Eureka, Fort Bragg, San Francisco, Monterey and Santa Maria. There are numerous valleys, including the Eel River Valley, the Russian River Valley, Sonoma Valley, Napa Valley, Santa Clara Valley, Livermore Valley and Salinas Valley. Each of these valleys tends to funnel the surface winds along the orientation of, or in line with, the valley. For example, King City, in the Salinas Valley, has wind that is either northwest or southeast 90% of the time. It is absolutely necessary for the forecaster to keep a picture in mind of the physical features of this area in order to predict the widely varying weather conditions that exist.

1. **<u>Geographic and Topographical aspects</u>**. Geographically, Moffett Field is in an advantageous location for a year round temperate climate. During the summer the combination of the Pacific high and the thermal low of the southwestern U.S. dominates the region, creating a constant onshore flow of maritime air over the area. California coastal regions which are predominately under the influence of maritime air do not experience the extreme temperature ranges of inland areas. Temperatures in the Sacramento and San Joaquin Valleys attain daily maximums of well more than 100 degrees in the summer. The summertime Pacific high also limits the migratory cyclonic storm systems from progressing southward, so they remain in the Gulf of Alaska or the Pacific Northwest coastal regions.

In the winter the Pacific high migrates to the southwest, allowing cyclonic systems to reach the bay area, although the intensity or severity of the transiting systems rarely reaches gale or storm warning criteria. Also, the California Sierra mountains and the Rocky mountains, to the east, provide an orographic barrier to the outbreaks of continental polar air, originating in central and northern Canada. Occasionally, continental polar air with a southwesterly trajectory will cross, or "spill over," the northern Cascades of British Columbia and then proceed southward, thereby affecting northern and central California and causing the extreme cold that sometimes occurs in the area. The coastal valleys are further protected by secondary mountain ranges on each side, which are high enough to reduce the worst effects of storms, by creating sufficient frictional effect to slow the movement of the systems. Onshore winds lose much of their energy before reaching the Santa Clara Valley due to traversing the coastal terrain. Consequently, forecasting is usually limited to evaluating variations in the maritime airmass, and the winter migratory lows which visit the area.

2. **Local Area**. Moffett Federal Airfield is situated at the southern end of the San Francisco Bay. Figure II-2 shows the immediate proximity of the Bay. The Bay terminates in salt flats adjacent to the northeast sector of the field. To the northwest, the Bay becomes a widening area of open water. The Santa Clara Valley extends to the southeast, with the closest point of the Pacific Ocean about 25 miles to the west.

Around Moffett Federal Airfield the important cities form an acute angle or wedge; San Francisco is 35 miles to the northwest, Oakland is 35 miles to the north-northwest, and San Jose is 9 miles to the southeast. There are a number of industries and light manufacturing plants along both sides of the South-Bay area and in the Santa Clara Valley. In recent years, visibility conditions have been affected by pollution from these industries and from vehicular traffic.

The terrain around Moffett Federal Airfield is such that it lies in a protective bowl formed by the northern ridges of the Santa Cruz Mountains paralleling the coastline with an approximate average elevation of 2000 feet. There are several peaks that reach elevations of 3000 to 4000 feet. Directly to the east are the Sunol and Valpe ridges of the Diablo Mountains, which begin a gradual ascent in the hills along the rim of the valley rising to 4000 feet. The most noteworthy peaks in the range are: Mt. Hamilton which is 4372 feet, Mt. Day which is 3939 feet and Mt. Diablo which is 3849 feet. The average height of this range is about 3800 feet. The Diablo Range and Santa Cruz Mountains run parallel to each other until 45 miles south of Moffett Field, at which point the termination of the Santa Cruz mountains forms the entrance to the Salinas Valley. This valley is formed by two ranges: the Santa Lucia Mountains on the coast and the Gabilan Mountains inland (See Figure II-1).

The western side of San Francisco Bay is more densely populated than the eastern side, particularly in the southern portions. Marshes and sloughs exist on both sides of the Bay to varying degrees. On the western side the small cities are closely linked while on the eastern side the population centers are more scattered with the maximum concentration around Oakland. From San Francisco and Oakland the San Francisco Bay merges into the San Pablo Bay to the north, which in turn becomes the Suisun Bay to the east. The sloughs and marshes surrounding the eastern San Pablo and Suisun Bays are much more extensive than around San Francisco Bay.

3. **Central California Area.** On the coast the ranges are broken by the bay inlet at San Francisco's Golden Gate forming a natural funnel for advective movement of low clouds and fog. The Diablo Range, as part of the Coastal Range system, continues relatively unbroken, forming the western boundary of the San Joaquin Valley. The two appreciable breaks in its contours are Livermore Pass (average altitude 900 feet), and the Carquinez Strait northeast of Moffett Field. These two passes facilitate passage into the San Joaquin Valley.

Bay Area Map

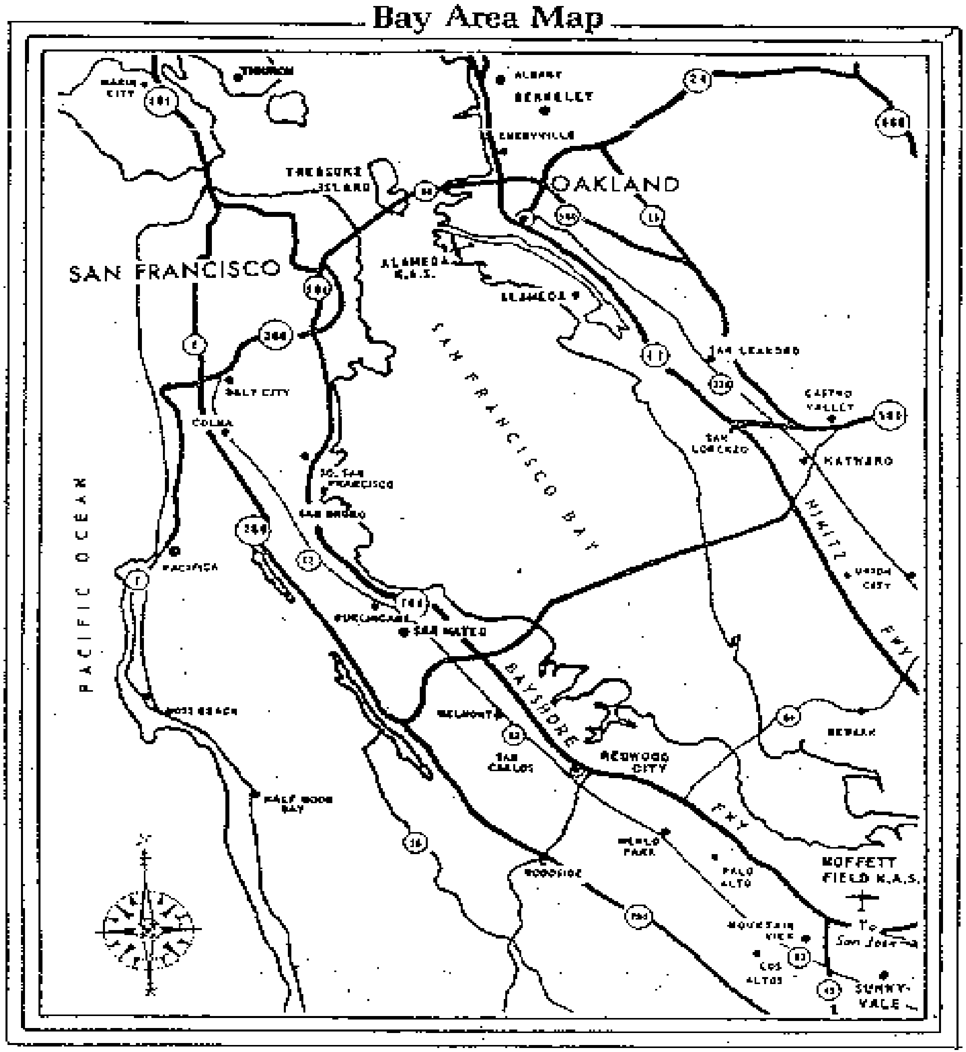


Figure II-2

II-4

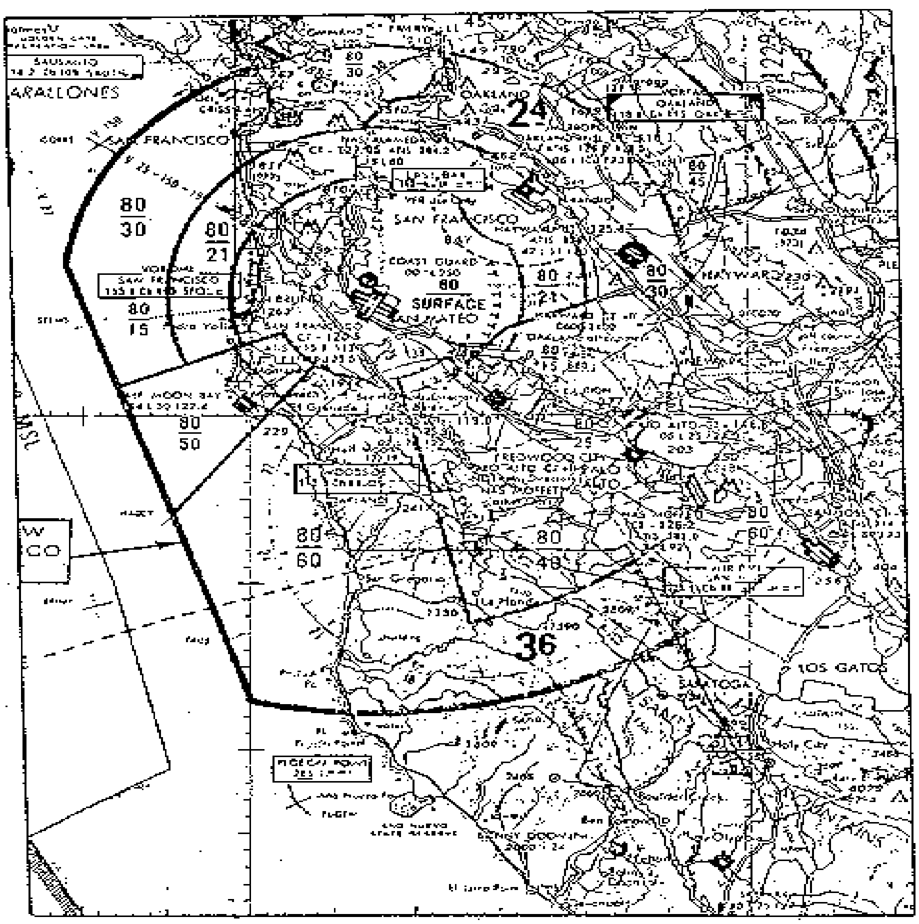


Figure II-1
TOPOGRAPHICAL MAP OF SAN FRANCISCO BAY AREA

II-3

To the north of San Francisco Bay, the Coastal Range begins in the Sonoma Valley and Vaca Mountains, and extends along the coast northward. The Sacramento Valley lies between this coastal range and the Sierra-Nevada Mountains. The Sacramento River, which empties into the Suisun Bay, extends inland up the Sacramento Valley to its headwaters near Mt. Shasta. The interior valleys (Sacramento and San Joaquin) average 100 miles in width from a point 100 miles north of San Francisco to south of Fresno.

B. Special Meteorological Features

1. **The Subtropical Pacific High.** The Bay Area lies on the eastern portion of the subtropical pacific high. This feature influences the Bay Area weather by seasonal variations in intensity and location. The mean position of the high-pressure center at the surface moves northward to near 40 Deg. N. in the summer and retreats southwestward in the winter to around 30 Deg. N. Figures II-3 and II-4 depict the seasonal variations of the Pacific High.

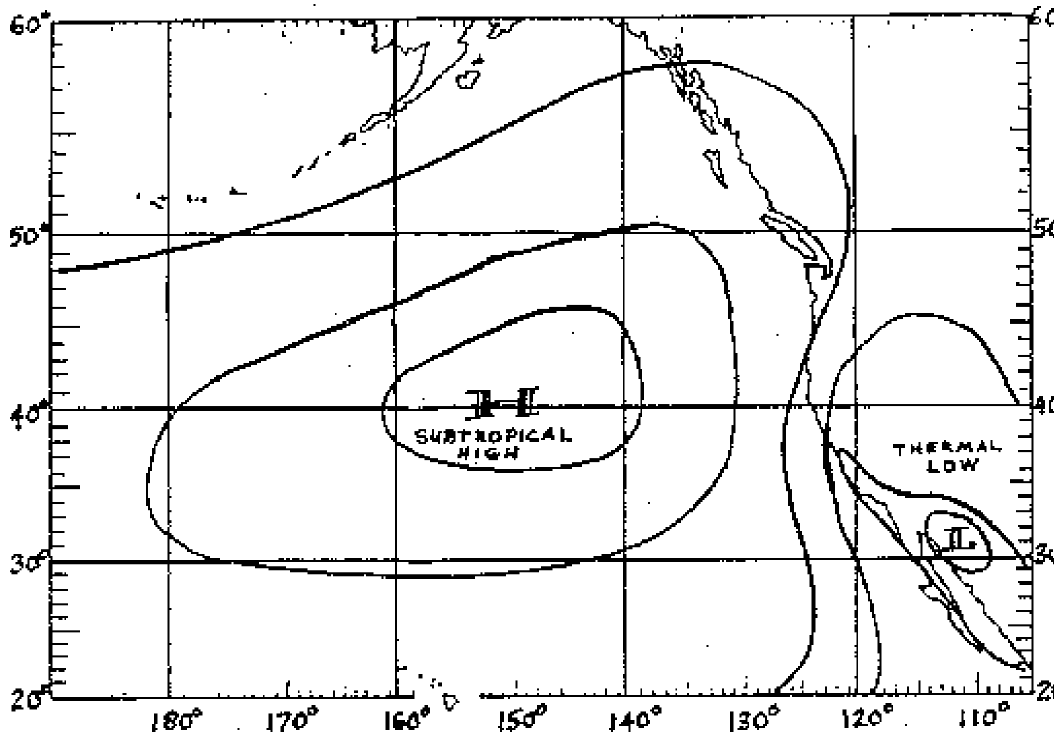
a. Summer.

(1) Pacific High normal position north of Hawaii. During the summer the northerly position of the high diverts storm tracks in a more northerly direction keeping the Bay Area essentially free of migrating lows and their associated fronts. The subsidence associated with the subtropical Pacific High combines with the relative cool, moist air at the oceans surface to produce the marine layer along the immediate coastline. Stratus clouds and fog form. Intensity and climatological position of the high for the most part remain constant during the summer, resulting in fairly stable meteorological conditions. However, on a day-to-day basis intensity and position of this feature will vary. The net result is that variations in the intensity of the Pacific High range from weak (which will generate only a gentle breeze) to strong (which produces winds strong enough to require small craft warnings).

(2) Pacific High ridge axis over the Pacific northwest. When the ridge axis builds inland over the northwestern United States, the air trajectory over the Bay Area will be offshore and downslope. This adiabatic warming situation gives the Bay Area warm, dry, cloud free, light wind conditions, with the normal stratus formation receding well off the coast or dissipating completely. Summer weather patterns are caused by the combined effects of the Pacific High, the thermal low of the interior valley, topography, the absence or presence of upper level clouds, and the depth or strength of the subsidence inversion above the marine layer.

b. Winter.

(1) Pacific High normal position between San Francisco and Hawaii. The subtropical Pacific High moves to the south during the winter months allowing, in part, for the development of the Aleutian Low. The increase in intensity of the Aleutian Low directs the storm track into the northwestern North American coast. Moving under meridional flow aloft, southeastward moving cold fronts pass over northern and central California.



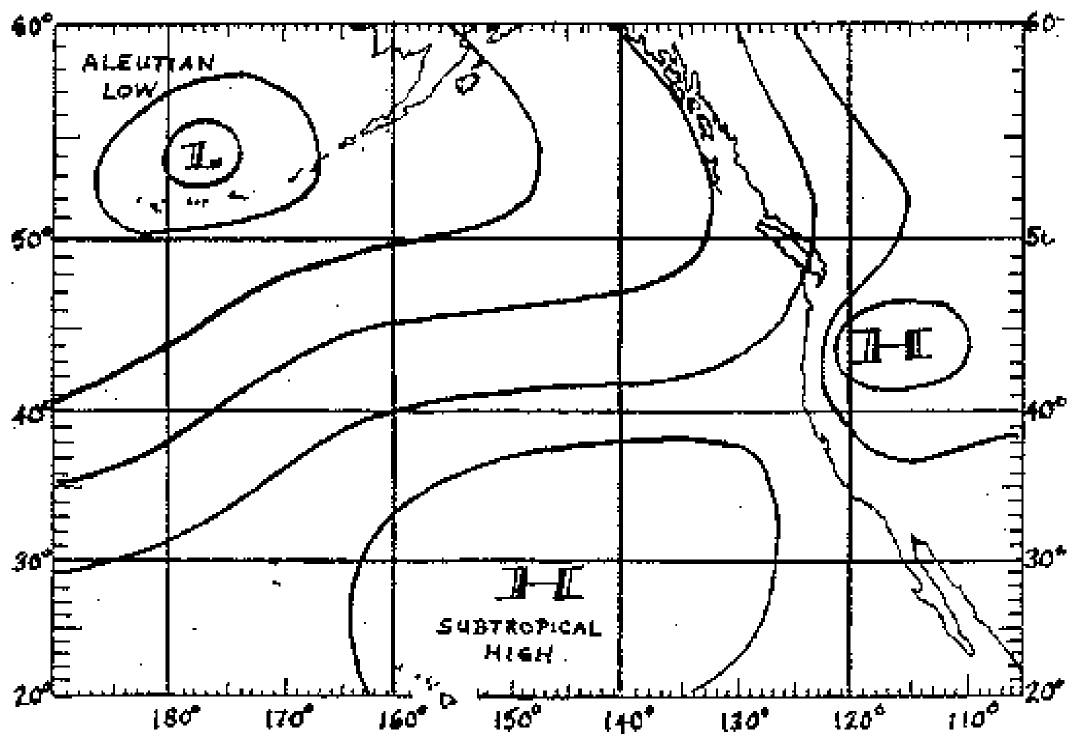


FIG. II-3 MEAN SEA LEVEL PRESSURE (SUMMER) TOP
FIG. II-4 MEAN SEA LEVEL PRESSURE (WINTER) BOTTOM

II-6

(2) Pacific High recedes south toward Hawaii. If the subtropical Pacific High retreats far enough south, the central California coast will typically lie under zonal flow and the storm track will be at that latitude. Fast-moving surface lows associated with short wave troughs will rapidly pass through the Bay Area. Warm and cold frontal passages will be observed under zonal flow conditions, as compared to only cold frontal passage associated with the "normal" Pacific High storm track scenario.

(3) Pacific High ridge axis over Pacific Northwest. If the Pacific High builds northeastward over Washington and Oregon, clear, cool, and dry conditions will be observed. The air Trajectory will be offshore or parallel to the coast at the surface and considered meridional aloft.

2. **The Aleutian Low.** The Aleutian Low is a semi-permanent low-pressure region associated with the polar front. The Aleutian Low is located in the vicinity of the Gulf of Alaska and the Aleutian Island chain. The low is most intense during the winter and essentially disappears in summer. During the winter short waves moving aloft in the circumpolar westerlies intensify as they move through the Aleutian Low. The storms then move eastward into Washington, Oregon, British Columbia and Alaska coasts with the trailing cold fronts moving southward and dissipating in northern and central California.

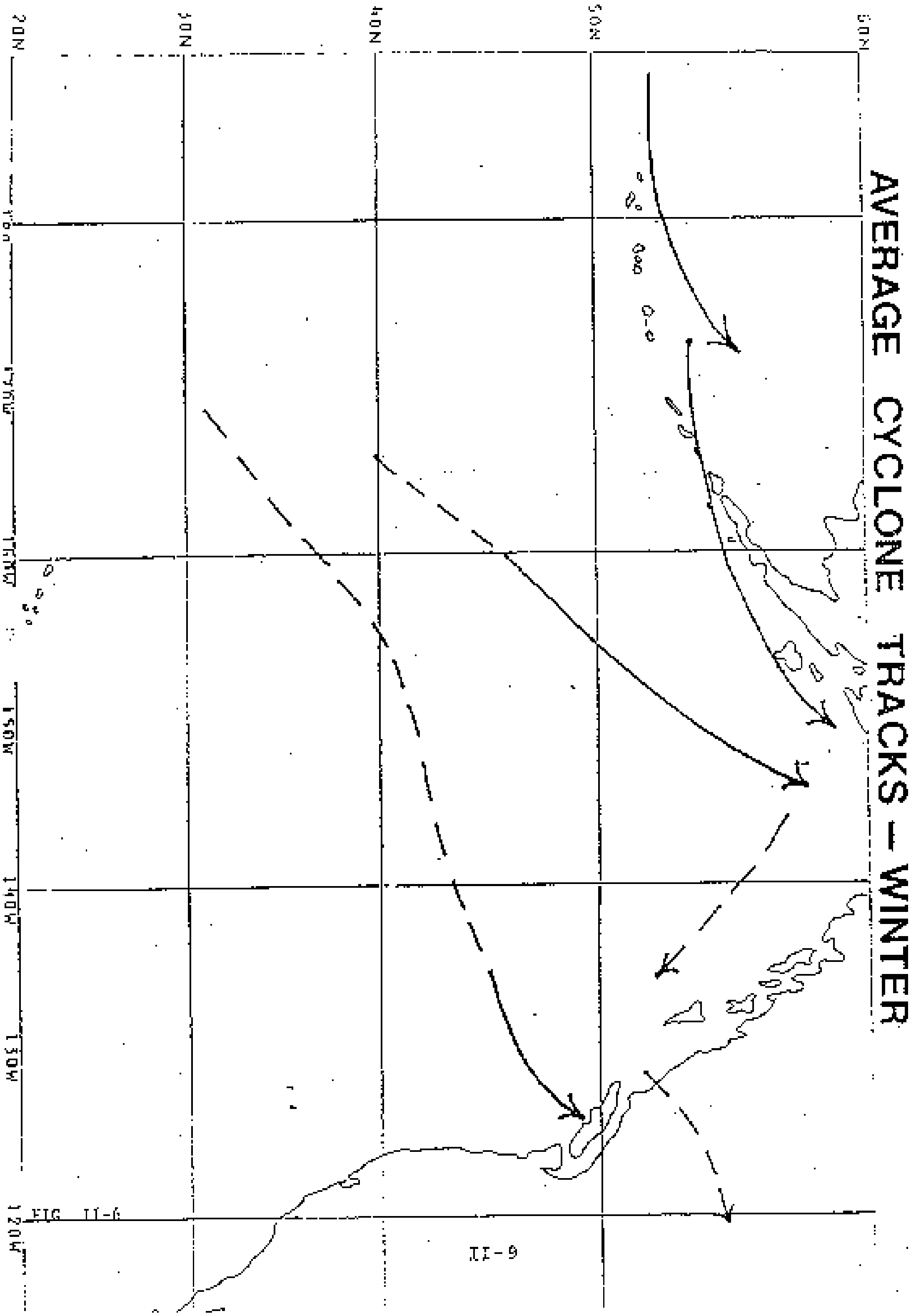
The position and intensity of the Aleutian Low vary slowly on a day-to-day basis as it interacts with the subtropical Pacific High. The low's east/west position and degree of intensity (e.g., "intense and digging deeply southward" to Hawaii, versus "weak and flat" approaching zonal flow) generates steering wind direction aloft influencing the storm track. During the course of winter, if the position and intensity of the Aleutian Low do not direct storms into the Pacific Northwest, the northwest portion of the North American continent will receive below average rainfall/snowfall and drought conditions will occur.

3. **Cyclones and Troughs.** The Bay Area is affected by several definitive cyclone and trough scenarios. They are: (a) extra-tropical maritime cyclones of the Pacific, (b) upper air cutoff lows to the west of Los Angles, (c) the summertime thermal trough or heat low of the southwest deserts and central California valley, (d)the Nevada Low and (e)eastern Pacific hurricanes.

a. Extratropical Maritime Cyclones. Extra-tropical maritime cyclones affect the Bay Area during the late fall, winter and early spring. Figures II-5, II-6 and II-7 are average cyclone tracks reproduced from the U.S. Navy Marine Climatic Atlas Volume II. The monthly storm tracks are divided into three seasonal groups. The winter months are those with the most intense storm activity affecting the Bay Area and results in the greatest observed rainfall. The summer months are an opposite situation with very little, if any, rain observed. The transition months have less intense cyclone activity but provide some rainfall to the Bay Area. Depending on the steering flow aloft there are two basic cases of maritime cyclone tracks to be considered: tracks associated with meridional flow (north-northwest) and those with zonal flow (westerly).

(1) Meridional Flow. As can be seen in figures II-5 through II-7, most cyclones form in the vicinity of the Aleutian Low and then move toward the northeast along the Polar

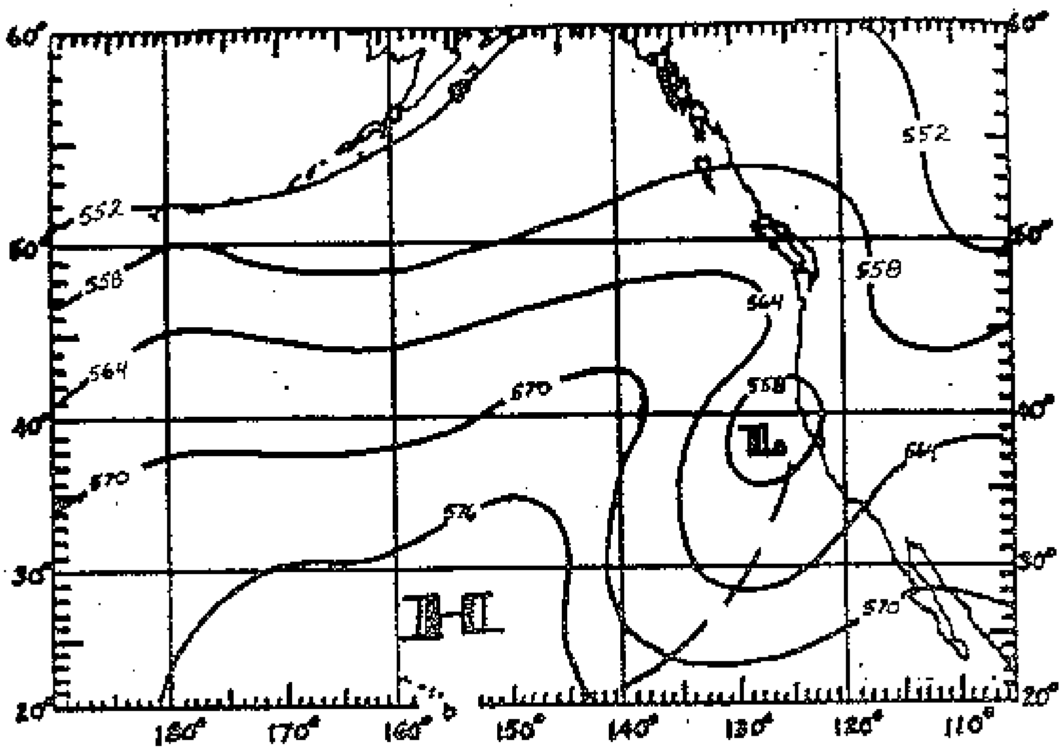
Front. The center of the low generally makes landfall along the northwest coast of the United States, Canada or Alaska. For the most part, storm centers do not come ashore in California. The cold fronts are driven south or southeastward by the polar outbreak of cold air associated with the storm systems. Since the polar outbreaks are strongest in the winter, it is then that more intense (increased rain and wind) and frequent frontal passages occur. During transition and summer when polar outbreaks are less severe and less frequent, fewer and less intense frontal passages are observed in the Bay Area.


AVERAGE CYCLONE TRACKS – WINTER
20N
30N
40N
50N
60N
170W
160W
150W
140W
130W
120W
FIG II-6
II-9

(2) Zonal Flow. During the winter months when the Pacific High recedes further south than normal, the Polar Front moves south and lies in an east/west orientation at the approximate latitude of San Francisco. Zonal flow aloft will steer rapidly moving shortwaves into the California coast. If the short-wave is strong enough it will be reflected as a surface wave on the Polar Front west of San Francisco. As the wave moves rapidly eastward it will intensify and bring rain to the Bay Area. If the wave is particularly intense, gale force winds can be observed inside the Bay, a very rare and unusual occurrence. The storm tracks do not clearly portray this situation. As a result of rapid movement over the relatively short distance between the storm formation area and the Bay Area, and the potential for higher than normal winds, the forecaster must be particularly alert to watch for cyclone development west of San Francisco during zonal flow situations during the winter.

b. Cutoff Low. Cutoff lows are usually associated with a blocking situation at upper levels, such that a sharp ridge is located west of the longwave trough or cutoff low position, oriented southwest to northeast at 500 millibars. These cutoff lows tend to occur just offshore of the California coast. As cold air plunges down the eastern side of a large amplitude ridge in the Gulf of Alaska an isolated pool of cold air and a closed low aloft may form (See figures II-8 and II-9). Occasionally, a strong ridge located in the Gulf of Alaska which has shown a pronounced tendency to move eastward onto the coast to produce a Santa Ana will suddenly stop and build. As the pressure in the Gulf region rises, the anticyclonic curvature around the crest becomes so great that the strong winds associated with the jet stream "overshoot" the top of the ridge and deepen the trough, forming a closed low aloft over southern California. As cold air continues to pour into it from higher latitudes, the low may deepen and move off the coast where it will stall, accumulate moisture, and produce an unstable, showery condition. One clue that is useful in forecasting the development of this cold cutoff low is the presence of a strong (1040mb or higher) stationary surface high at the more northern latitudes of the Gulf of Alaska.

c. Thermal Trough (Low). During the spring there is an increase of solar heating in the deserts and valleys of southwest and central California. This seasonal occurrence allows a quasi-stationary low-pressure area to develop northwestward from central Mexico. As summer progresses, intense heating of the Central Valley continues. The lack of strong, cooler air masses entering the valley allows the thermal trough to remain a permanent feature. The interaction between low pressures of the thermal trough and the higher pressures of the Pacific High forms a strong pressure gradient. The thermal trough fluctuates in intensity over several days. When the trough is most intense, a low-pressure center and associated circulation will establish themselves in the valley. As the hot air in the valley rises, the winds created by the onshore flow pressure gradient penetrate the central valley and temperatures decrease with the arrival of cool, dense, marine air. As temperatures cool pressures rise, weakening the gradient thus decreasing the supply of cool dense air in the Central Valley. The air temperature begins to rise again, repeating the cycle. When the pressure gradient is strong, the winds will be strong carrying with it cooler temperatures and stratus. When the pressure gradient is weak, winds are weak and daytime temperatures will be relatively warm with the stratus remaining offshore.



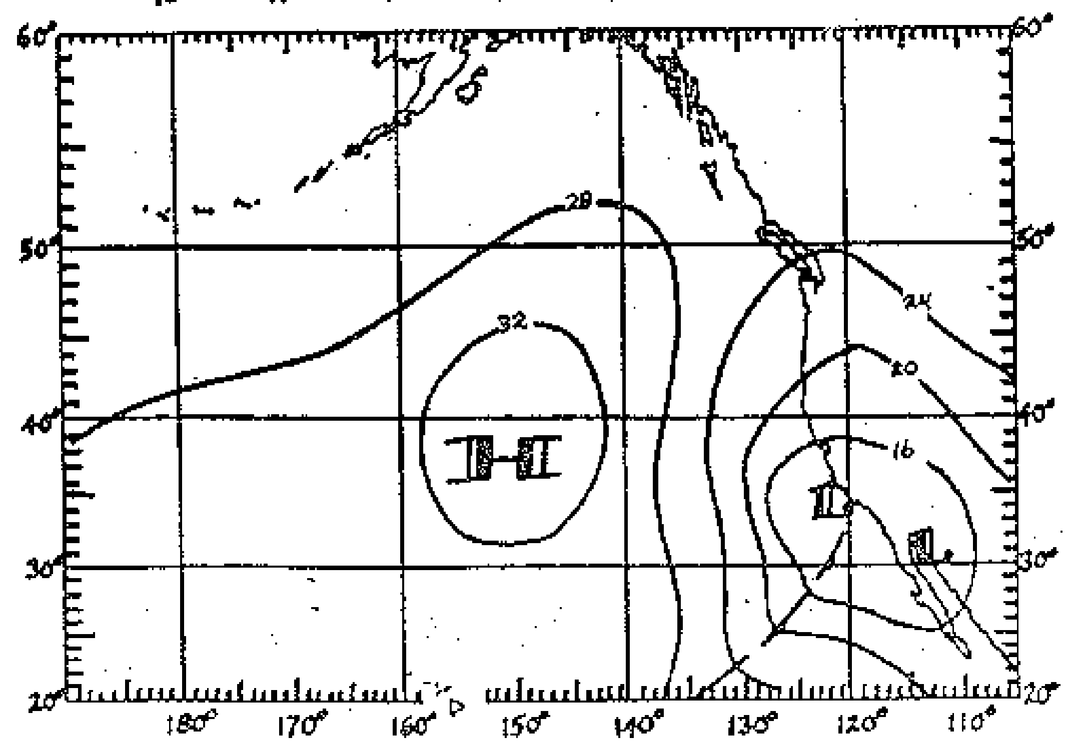


FIG. II-8 CUTOFF LOW 500 MB.
FIG. II-9 CUTOFF LOW SURFACE.

II-11

d. <u>The Nevada Low.</u> The Nevada or "Tonopah" low is the name given by west coast forecasters to the synoptic situation that develops when stationary low pressure is observed over the Great Basin and southern Nevada. Formation occurs during fall, winter and most commonly, spring. Coincident with the development of the Nevada Low, a stronger than normal high pressure system is observed off the California coast with ridging over the Pacific Northwest states into southwestern Canada (figures II-10 and II-11). The resultant flow advects cold air from the interior of Canada into the warmer air mass over the Great Basin. This unstable situation may be intensified by one of the following mechanisms: (1) A wave on an east-west oriented front, (2) A secondary low in an unstable air mass behind the passage of a frontal low, (3) A jetmax over the area. The strong pressure gradient associated with this synoptic situation typically produces <u>sustained small craft wind conditions</u> in the Bay Area and <u>gale force</u> winds along the entire California coast. In the Bay Area, weather will generally be clear to partly cloudy with cool temperatures. In the interior of the state, winds will be stronger with cumuliform clouds and/or thunderstorms. On the eastern slopes of the Sierra Nevada and extending into central Nevada, widespread low ceilings and heavy precipitation is observed. Nevada lows move eastward and intensify, at times causing severe weather east of the Rockies.

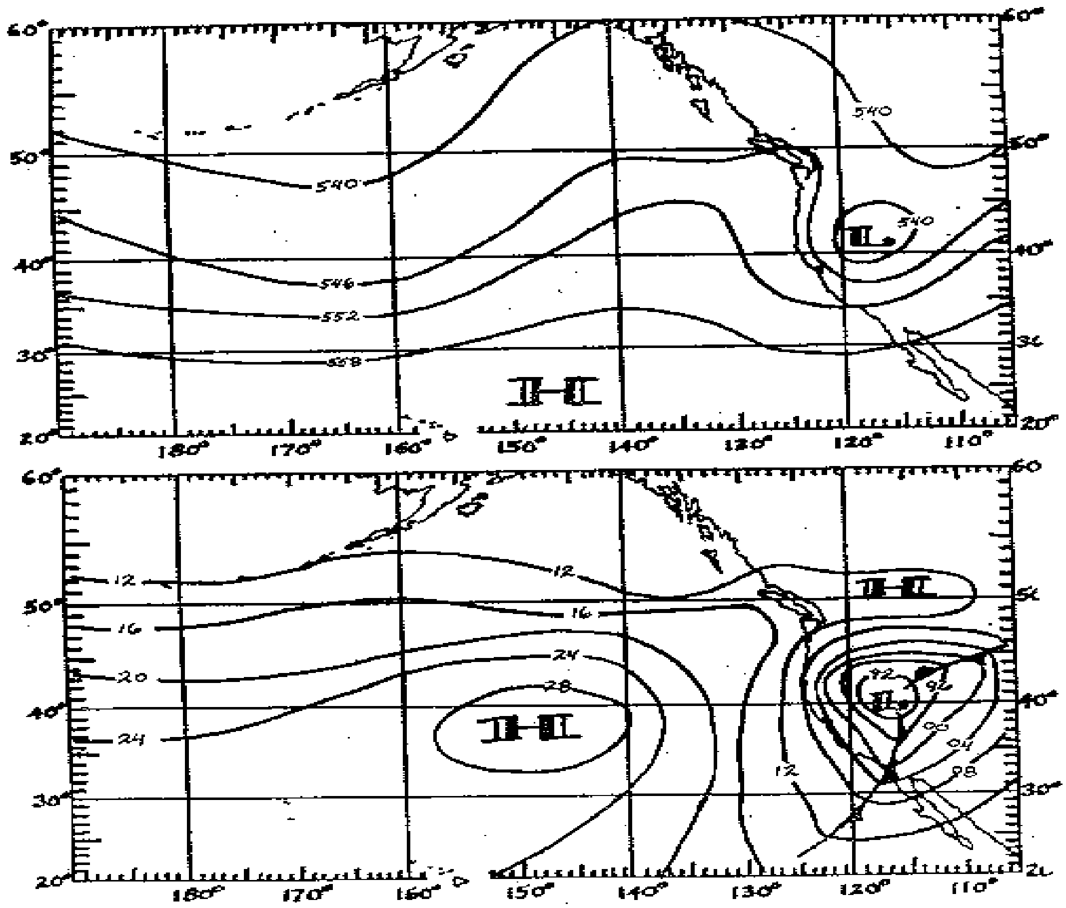
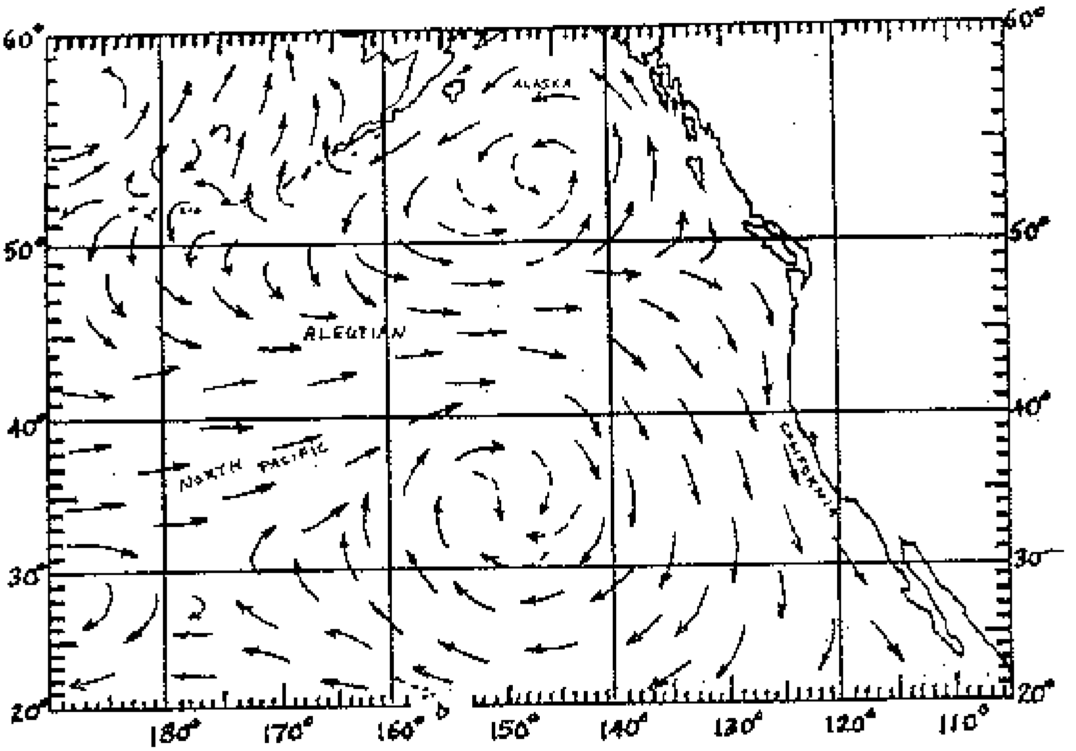


FIG. II-10 NEVADA LOW 500 MB.
FIG. II-11 NEVADA LOW SURFACE. II-13

4. **Pacific Ocean.**

a. Sea Surface Temperature (SST). The SST is important for a variety of Naval uses, especially in submarine warfare because of its propagation of sound. Related in many ways to subsurface thermal structure, SST is a key feature in predicting oceanographic conditions. Figures II-12 through II-15 show the average monthly SST throughout the eastern Pacific Ocean. From the SST charts it can be determined that the minimum SST in the vicinity of the Bay Area occurs between March and April while the maximum SST occurs between September and October. During late spring, summer and early fall, the prevailing northwesterly wind in conjunction with the southerly flowing California current (see figure II-16) creates an upwelling of the subsurface cold waters along the Pacific coast. This wind driven current tends to change direction with depth resulting in a net outflow of the upper water layer near the coast. Upwelling can be discerned from the SST charts by locating troughs or tongues of cold water flowing in a southerly direction away from the coast. At the same time, tongues of warmer water separate the tongues of colder water and can be seen flowing north, protruding toward the coast. By late fall upwelling has ceased and a countercurrent, in the surface waters known as the Davidson current (figure II-17), becomes dominant and flows northward along the coast to about 48 deg N latitude. This current creates a relatively stable layer cutting off the interaction between surface and subsurface water and lends to a relatively smaller seasonal rise of temperature below.



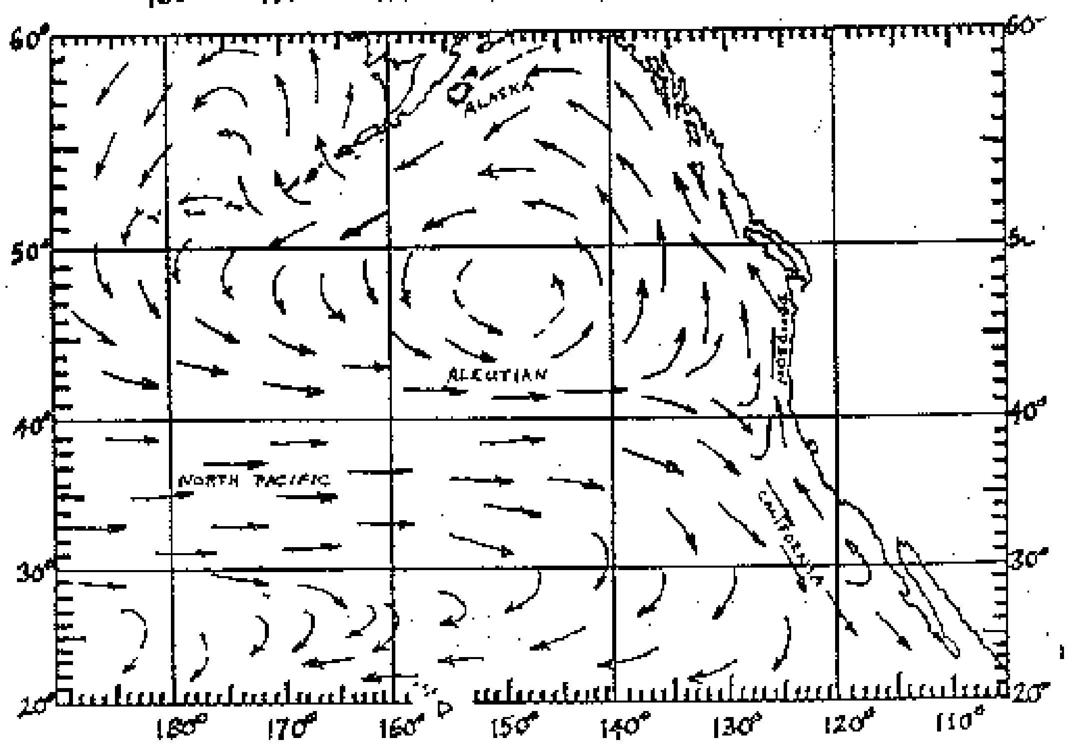
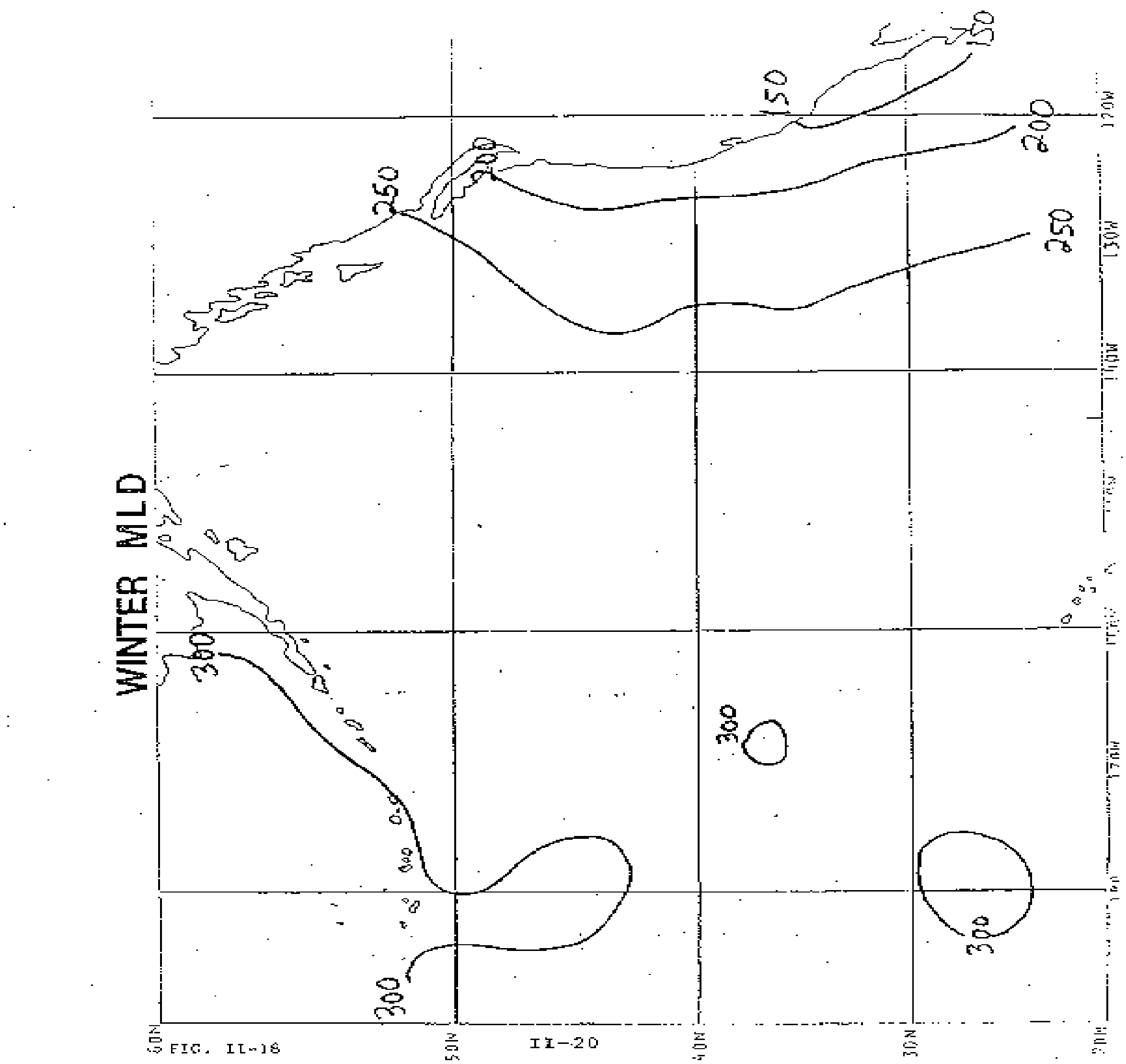


FIG. II-16 SUMMER SURFACE CURRENT CHART TOP
FIG. II-17 WINTER SURFACE CURRENT CHART BOTTOM II-19

b. Mixed Layer Depth. During January through March, (figure II-18) mixed layer depths are relatively stable maintaining an average depth less than 200 feet in the northern and southern California Op-areas. April through August (figures II-19 and II-20) marks a trend toward more shallow layer depths throughout the eastern Pacific Ocean. By August the mean layer depth over most of the northern and southern California Op-areas is less than 100 feet. The shallow mixed layer depth in the spring and summer months is a result of the stabilizing effects of a positive heat exchange in the near surface layer, and the greatly reduced mechanical mixing is due to weak prevailing winds. During the fall and winter months the mixed layer depth deepens significantly due to convective overturn caused by net oceanic heat loss at the surface from cooler air temperatures and mechanical due to increased winds and seas from storm activity. A steady deepening of mixed layer depths is noticeable September through December (figure II-21).



SUMMER MLD

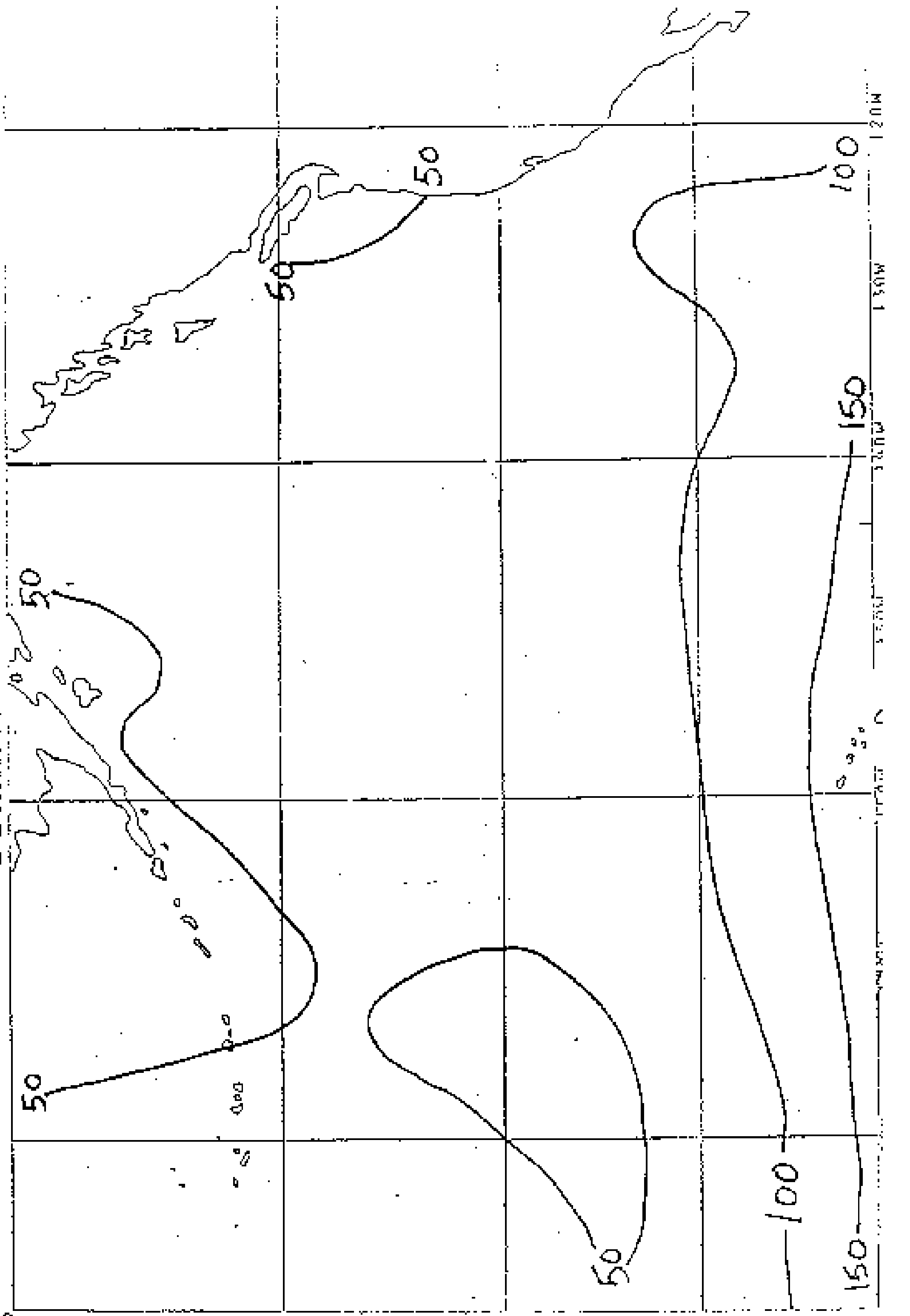
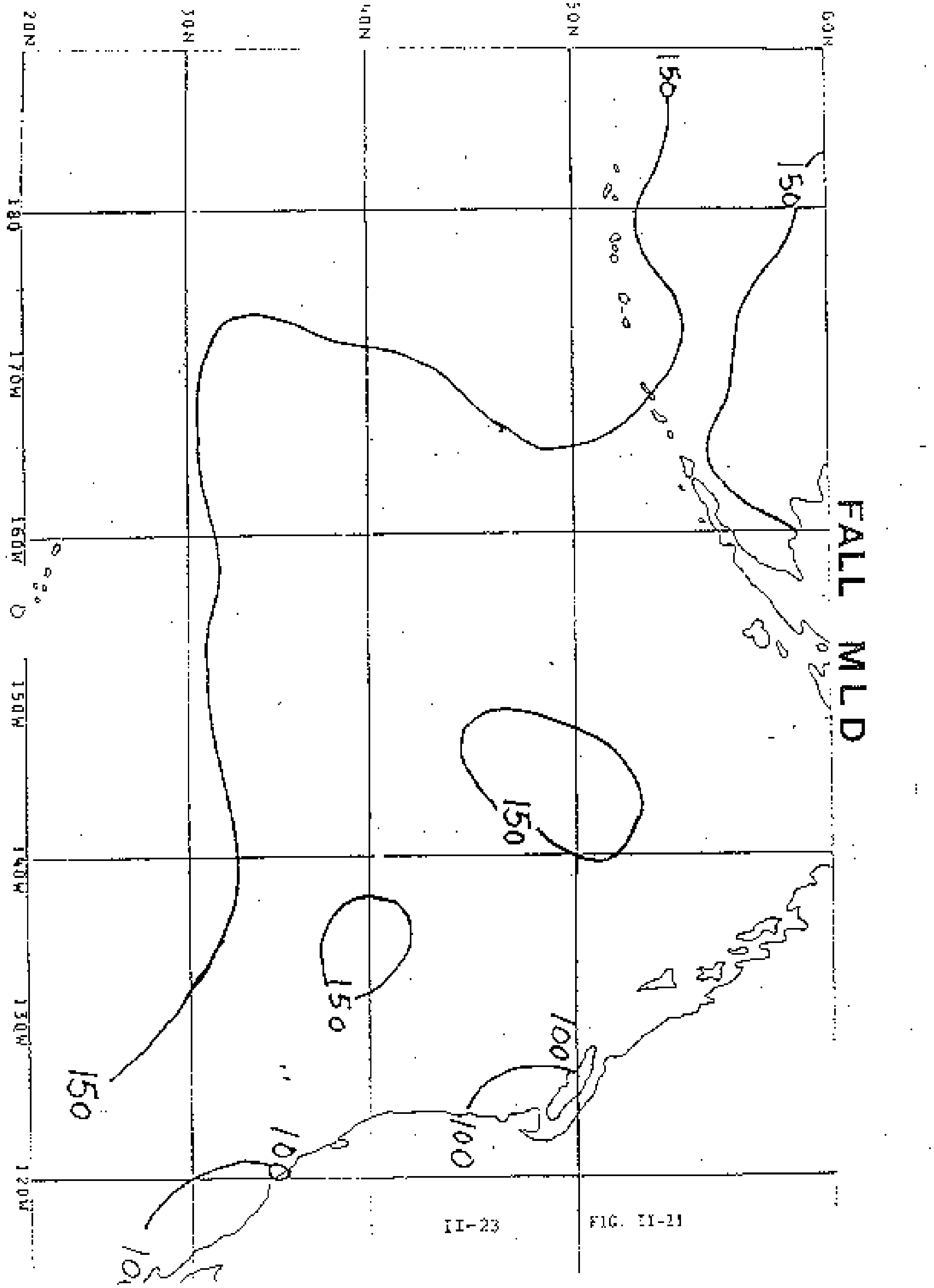


FIG. II-20

II-22


FALL MLD
20N
30N
40N
50N
60N
180
170W
160W
150W
140W
130W
120W
150
150
150
150
150
100
100
100
II-23
FIG. II-21

5. **Sea Breeze.** The sea breeze in the South Bay area dominates from the end of may through the end of September. The primary cause of the sea breeze circulation is the temperature contrast between the level of the sea surface, which becomes the greatest at the time of maximum diurnal heating; hence, this is normally the time of highest sea breeze velocity. The sea breeze is substantiated by the general summertime synoptic pattern for the West Coast; namely, the thermal trough or low over the inland valleys and the high pressure cell in the eastern pacific. The afternoon sea breeze effect may exist at other times of the year, but it is usually weak (see figures II-22 and II-23).

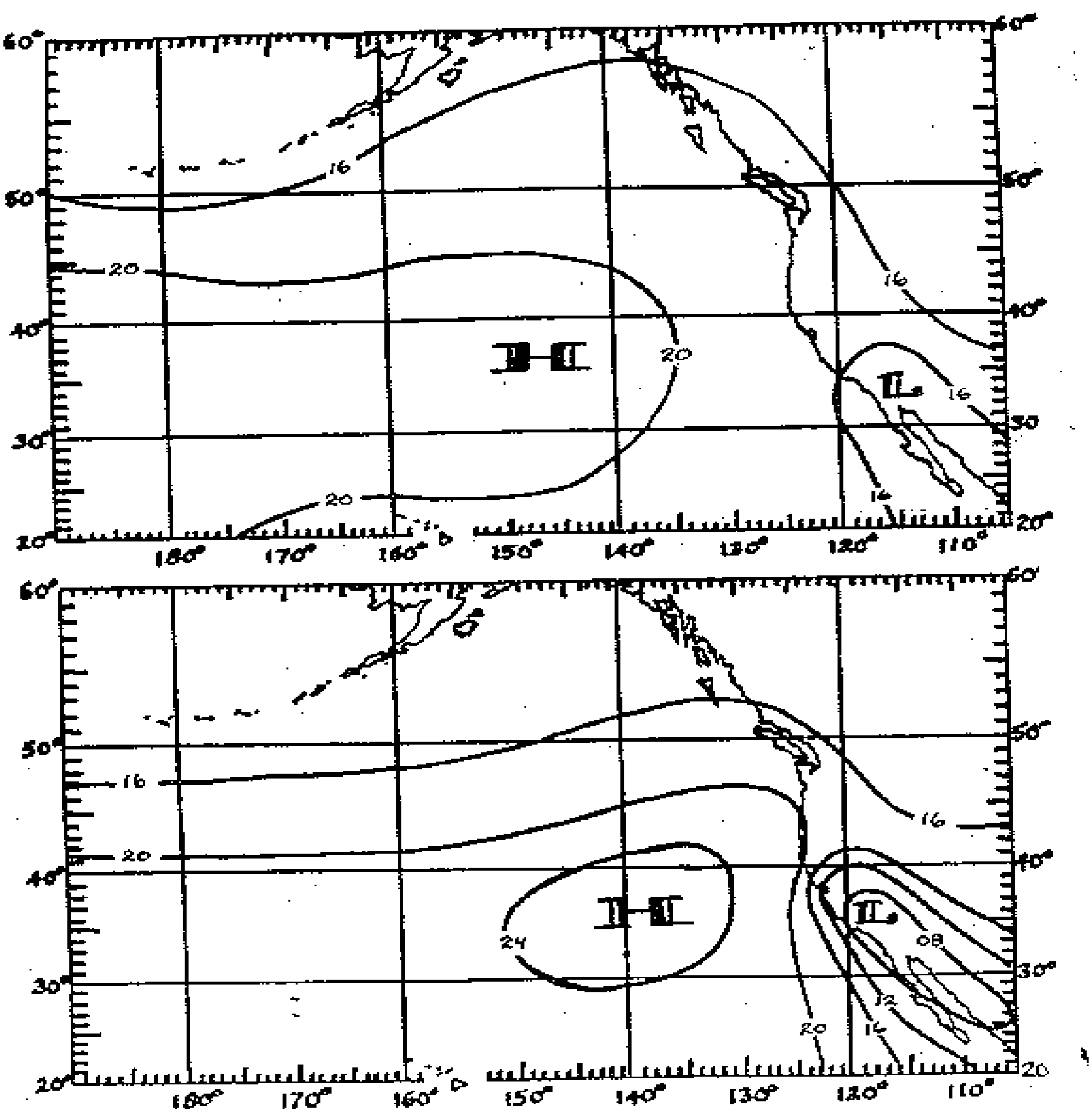


FIG. II-22 LIGHT WIND TOP
FIG. II-23 HIGH WIND BOTTOM

II-24

The prevailing direction of the sea breeze at Moffett Federal Airfield is north-northwest with speeds of 12 to 18 knots, occasionally reaching 20 knots with local gusts to 25 knots in the late afternoon. During the late evening and early morning hours, the winds are light and variable. The sea breeze usually kicks in just before noon and ends between 1900 and 2200 PST. The afternoon flow is given some impetus by the local topography, (i.e., the funneling caused by the northwest-southeast orientation of the valley and the associated mountain ridges). It loses some of its original velocity at its onset due to the uneven coastal terrain. Therefore, this station does not experience high velocities, as do some stations in the San Francisco Bay Area. Major modifications of the sea breeze are brought about by the existing pressure pattern and alignment of the pressure gradient, which may cause an opposing force to detract from the sea breeze effect.

6. **San Joaquin Valley Low Level Jet**. The summer nocturnal jet over San Joaquin Valley has been known to exist for several years. Knowledge of the strength of the low level jet, its vertical extent and wind speed distribution through the valley, is valuable to aviation interests, fire fighting officials and air pollution control agencies. The jet was studied by NOAA (1972) as project Lo-Jet. The following information is derived from the NAS Lemoore Local Forecasters Handbook:

During the summer, the low-level jet occurs almost nightly. The jet forms near sunset, reaches a maximum strength during the evening and prevails most of the night, gradually decreasing in intensity.

Caused by large-scale thermal and synoptic pressure patterns, the nocturnal jet is dependent upon the intensity of the eastern Pacific High cell and the southwest thermal low. Maximum intensity of the low-level jet occurs during the hottest portion of summer, when thermal troughing is best defined. The jet is weakest when the marine inversion along the coast becomes sufficiently deep to allow cool air to spill into the San Joaquin Valley weakening the thermal low over the interior.

A vertical structure of the jet during maximum inflow periods, shows surface wind speeds of 10 to 15 knots gradually increasing to a maximum of 25 to 35 knots between 1000 and 2000 feet (305 to 610m), then gradually decreasing to 10 to 15 knots at 4000 feet (1220m). The information available as to the horizontal extent of the jet shows it to be present over the entire San Joaquin Valley and of nearly equal strength from east to west. The maximum velocities will be found in the north and central portion of the valley. The prevailing wind flow is west or northwest through the valley, except for the eddy effect in the extreme southern end.

The Moffett Federal Airfield forecaster must be aware of the significance of the low-level jet in order to advise pilots of light aircraft and helicopters flying over the central valley in the late afternoon and into the night. The presence of the jet affects navigation, fuel planning, and low-level turbulence forecasts.

7. **Advection Fog/Stratus of the California Coast**. Off the northern California coast there is a narrow band of cold water caused by upwelling ocean currents. Even in the summer the

water off San Francisco is colder than coastal water 900 miles to the north. The prevailing westerly wind transports warmer, moister air over the cold coastal waters (see figure II-24). As air passes over the colder water, it cools forming advection fog and/or low stratus. At the same time a temperature inversion of five to 12 degrees C. nearly always exists with the base of the inversion varying in altitude from 800 to 3000 feet, effectively confining the top of the stratus or fog layer. The base of the stratus/fog deck varies from the surface to 2000 feet depending on the upper atmospheric conditions and the strength of the surface winds.

During the day long wave radiation from the sun penetrates the stratus layer, warming the earth. The fog lifts off the ground while short wave radiation dries the layer from above. If the stratus layer is less than 1500 feet thick, it eventually dissipates over land between 0800L and 1400L. Occasionally, the stratus is so thick that it persists all day. Normally this occurs along the coast where the westerly flow continually advects air onshore from colder water. Fog or low stratus decks exist over the cold seawater throughout the summer and persist over coastal valleys for days at a time. During the mid-summer months of July and August a veritable stream of fog

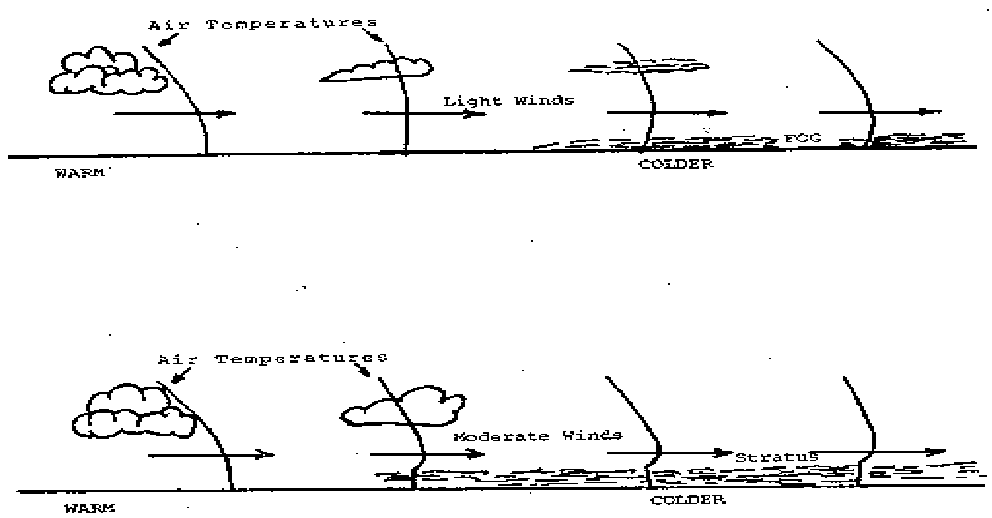


FIG. II-24 PASSAGE OF WARM AIR OVER A COLD SURFACE.

II-26

or low stratus flows through the Golden Gate almost every afternoon. The stratus will advect across the Bay towards the Berkeley Hills where it divides and flows north and south along the base of these hills. On occasion it is so thick and persistent that it will swing around to the Oakland airport. Such a phenomenon explains why a field can change from unlimited to zero conditions in less than thirty minutes.

The coastal range, varying from 200 to 500 feet in elevation, forms an effective barrier to this low stratus. Sacramento and San Joaquin Valleys remain clear and dry all summer long. Thus, if a pilot gets caught above the overcast along the coast, a suitable alternate can nearly always be found east of the coastal mountains.

8. **Radiation Fog**. The winter season is almost free of advection fog; however, on clear cold nights sheltered valleys will frequently be blanketed in the early morning hours with a thin layer of radiation fog. This fog is seldom over 500 feet thick and dissipates 2 to 3 hours after sunrise. In the interior valleys one or two days after frontal passage radiation fog will form and persist for two to three weeks.

a. Radiation Fog in the San Joaquin and Sacramento Valleys. Several times each winter moist maritime air flows into the interior valleys of California. This maritime air is usually transported to the interior areas through frontal activity where it stagnates due to weak pressure gradient. Light northeasterly winds aloft from 5000 to 10000 feet bring dry stable air from Nevada over the Sierra Nevada and down over valley areas, thus causing an inversion over the cool moist air near the ground. Due to clear skies, intense radiational cooling takes place and the ground becomes cooler than the dewpoint of the air immediately above the ground, causing radiation fog. As long as the layer of maritime air remains stagnated, radiation fog persists.

The burning off process is slow, commencing around the outer edges near the higher elevations first. On occasion the valley may remain fog bound or low overcast with a stratus deck for 12 to 16 consecutive days. Usually the only thing that will eliminate the condition is the approach of a cyclonic depression from the west, or troughing in the upper strata above 5000 feet. The approach of the depression sets up a wind strong enough to remove the stagnant wet air mass lying close to the valley floor and virtually eliminates the temperature inversion. During these periods of persistent valley fog, the coastal stations remain open except for early morning periods of radiation fog. On rare occasions, if the surface strata winds are light and variable from the northeast, the fog bank will penetrate through to the Livermore valley to the south of the Bay Area.

C. Synoptic Meteorological Patterns.

1. **Monthly Summaries**. January is normally the coldest month of the year with the mean temperature curve reaching a minimum. The ‘rainy season’ peaks and several frontal systems pass through the area. Frontal passages are often accompanied by squally conditions. Southeast wind prevails slightly more than northwesterly wind. GCA minimums occur 2.6% of the time due to radiation fog caused by the near surface temperature inversion. Near freezing temperatures may be expected on several mornings.

February initiates the decline of the winter season with an increase in temperatures and a decrease in mean rainfall. Fog occurs on an average of four days causing field conditions below GCA minimums. When radiation fog develops, it usually occurs on several consecutive mornings. Four to five frontal passages can be expected during the month with prefrontal gale force winds followed by postfrontal squalls. One or two clear days may be expected following frontal passage with cloud conditions changing as the relatively dry air mass is modified. Ideal radiation cooling conditions may cause below freezing temperatures in the early morning hours.

March begins the transition between winter and summer seasonal weather phenomena. Weather conditions between frontal passages are milder with a definite increase in the percentage of clear days. Prevailing wind velocities increase slightly with the prevailing direction being north-northwest. Mean temperatures are on the increase, but freezing temperatures have occurred on clear nights.

In April, normally only two or three fronts pass through the area with a high percentage of clear days. Ceilings from coastal stratus are limited to brief early morning periods averaging two days during the month. Only one freezing temperature has been recorded during April with the mean temperature 4 degrees higher than in March.

May marks the end of the rainy season and the transition to the summer stratus regime. Coastal stratus is the predominant cause of IFR conditions advecting over the field near midnight with ceilings from 800 to 1400 feet. Stratus ceilings normally dissipate around 1100 PST. The summer northwesterly sea breeze becomes well established during May with afternoon maximum winds averaging 15 knots. Rainfall during this month is less than ½ inch occurring early in the month.

The nocturnal ingress of coastal stratus into the Bay region is a recurring phenomenon during June. The northern movement of the Eastern Pacific High combined with the developing thermal low over the California desert regions cause sporadic night and early morning stratus to advect over the field. Bases of the stratus deck is normally above 600 feet with visibility over 3 miles. Due to the increase of industrial activity in the area, visibility will sometimes be less than 3 miles in haze and smoke throughout the day. Surface winds are light and variable during the night and early morning with northwesterly sea breezes prevailing in the afternoon.

July is the midpoint of the summer dry season. Flying conditions are excellent in the afternoon and evening. Late night and early morning stratus will increase the frequency of ceilings below VFR minimums. Haze and smoke will frequently stagnate during the day after the dissipation of the stratus clouds.

Good flying weather may be expected in August with an average of only two hours per month below IFR minimums. Weather conditions below VFR minimums can be expected about 13 days of the month. IFR conditions almost always occur during the late night and early morning hours as a result of the stratus clouds. Occasionally IFR conditions will persist through the afternoon due to concentrated smoke and haze. The prevailing north-northwest wind is augmented by the afternoon sea breeze effect.

September remains warm and dry, conditions similar to July and August with the exception of the decrease of stratus. About 30% of the years of record indicate no measurable precipitation. Flying conditions are above VFR minimums 91% of the time. Low stratus, smoke and haze conditions hinder VFR flights. The afternoon northwesterly sea breeze prevails.

October, normally a month of good weather, heralds the onset of the winter rainy season. Rainfall is associated with an average of three frontal passages occurring during the month. The temperature begins a seasonal downward trend with the monthly mean about 4 degrees below that of September. The prevailing wind is the northwesterly sea breeze; however, gusty southeasterly winds can be expected with frontal activity.

November, with its marked increase in precipitation and fog, begins the winter season. An average of four to five fronts can be expected to transit the area during the month. Radiational fog (rather than prefrontal fog) will cause reduced morning visibilities. Although generally weak, frontal activity will occasionally cause moderate rain and strong gusty winds both preceding and during frontal passage. A definite cooling trend occurs with freezing temperatures possible on several mornings. Good flying conditions remain; however, instrument conditions tend to be more severe and persistent than September or October.

The transition to winter season has been completed by December with frequent frontal activity. Moderate precipitation and strong gusty winds can be expected with frontal passage. Temperatures continue the downward trend with the monthly mean temperature dropping below 50 degrees. Under ideal nocturnal radiation conditions, early morning temperatures may drop below freezing. Due to dense radiation fog, weather causing GCA mins can be expected on an average of 2.3% of the time. South-southeasterly winds prevail.

2. **Winter Synoptic Storm Patterns**. Adverse weather conditions in the area (caused by migratory cyclonic disturbances) generally result from one of the three basic patterns.

a. Occluded Front Moving in from the West. This type pattern is common whenever a well developed 500mb and 300mb-longwave trough becomes established near 140 to 145 degrees west. A family of low-pressure cells will usually develop on the Polar Front, with a least one warm type occlusion positioned along the West Coast in a normal four-day cycle. A typical sequence of frontal movement is shown in figure II-25. History indicates that this pattern will result in vigorous frontal activity in the Bay Area when the 500mb trough progresses toward the coast. If the mean longwave trough in the upper strata remains west of 140 degrees west with the surface system just off the coast of California and Oregon, frontal passage in the South Bay will be relatively mild. Considerable precipitation in the South Bay is expected with the warm occlusion particularly if the colder air is trapped between the coastal and Diablo mountain ranges. With this situation of moderate cyclonic activity, warm, moist maritime air is continually brought in from the Pacific. Classic overrunning of warm air is augmented by the orographic lifting influence of the coastal mountains. Precipitation is steady for 6 to 18 hours.

With the frontal activity following the general trajectory shown in figure II-26, there are times when cyclogenesis on the front will occur in the vicinity of 30 degrees north and 140 degrees west. When cyclogenesis does occur in this area, expect rapid deterioration of the California coastal weather within 30 hours. This situation is likely to occur when the southerly winter jet stream, oriented west-east, is situated near 25 degrees north. A typical 500mb pattern is depicted in figure II-26. A good indicator for surface development in this area is a rapid increase in the west to southwest over the area at 500mb and 300mb. A vigorous shortwave trough moving through the longwave trough is the usual indicator of cyclogenesis in this area. Surface winds from this occluded pattern will shift to the southeast at least 24 hours before frontal passage and gradually increase in velocity as the front approaches. The strongest wind may be expected within 6 hours of frontal passage with post-frontal winds subsiding rapidly. Only partial clearing should be expected until passage of the 500mb trough.

b. <u>Cold Front Approaching the Field from the Northwest.</u> This is the most common of the winter frontal systems that affect the Bay Area. Although there are several minor variations, the three most common variations to the general type follow:

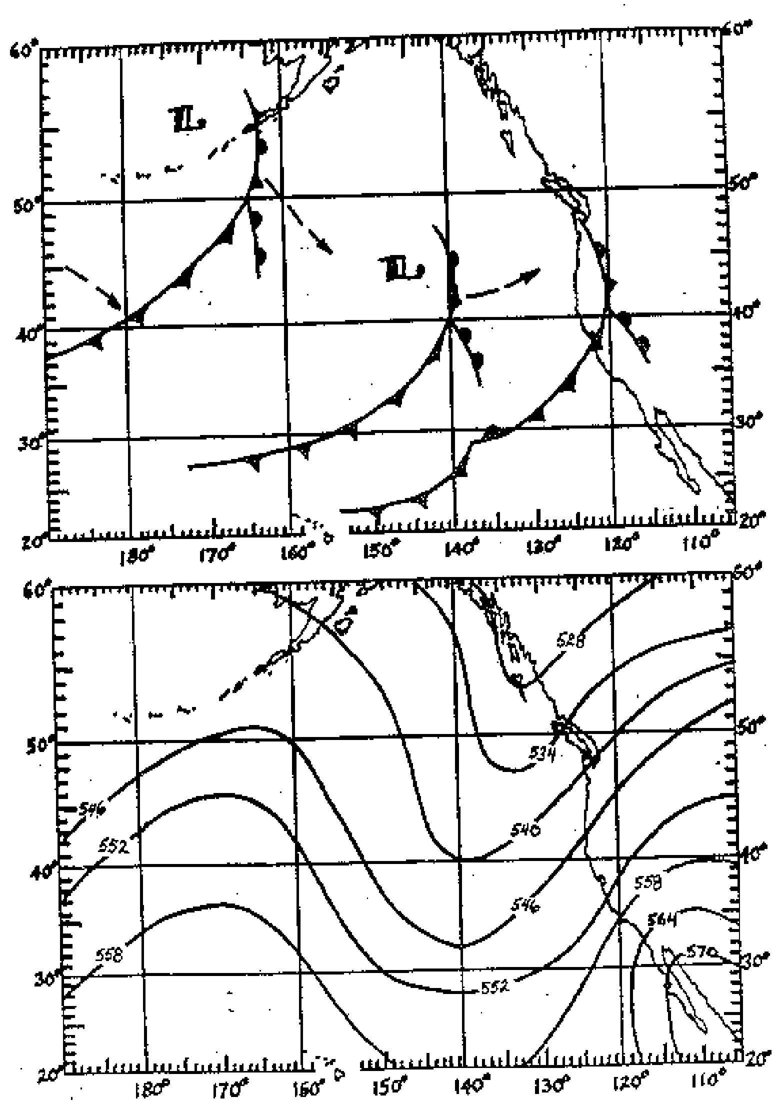


FIG. II-25 OCCLUDED FRONT SEQUENCE (WESTERLY TYPE)
FIG. II-26 500 MB. FLOW FOR COLD FRONT
II-30

(1) A 'SKAGERRAK' occurs along the British Columbian coast. The main storm track is just south of the Aleutian Island chain through the Gulf of Alaska. A typical sequence of frontal movement is shown in figure II-27. The regenerated low and associated frontal system moves east-southeast and rapidly becomes the main storm center. The flow aloft is slightly meridional with a major trough near the dateline and ridging between 135 and 145 degrees west. The 500mb-flow pattern will be similar to that depicted in figure II-28. A vigorous shortwave trough will be well defined at the 500mb level when the 'skagerrak' condition occurs. The

occluded portion of the regenerated frontal system usually dissipates in eastern Washington and Oregon with an active cold front extending southwestward through northern California. The progress of the front can be readily tracked as it moves down the coast. Surface wind usually shift to the southeast 10 to 15 hours prior to frontal passage. Pre-frontal winds are usually 5 to 10 knots sub-gradient as the normal gradient floe is southwest. Precipitation is usually in the form of light, intermittent rainshowers. However, intermittent rain will also occur if the flow aloft is southwesterly. Rapid clearing should not be expected, as in many cases the main trough near the coast retrogrades slightly. Rapid clearing will occur when the wind shifts to the northwest.

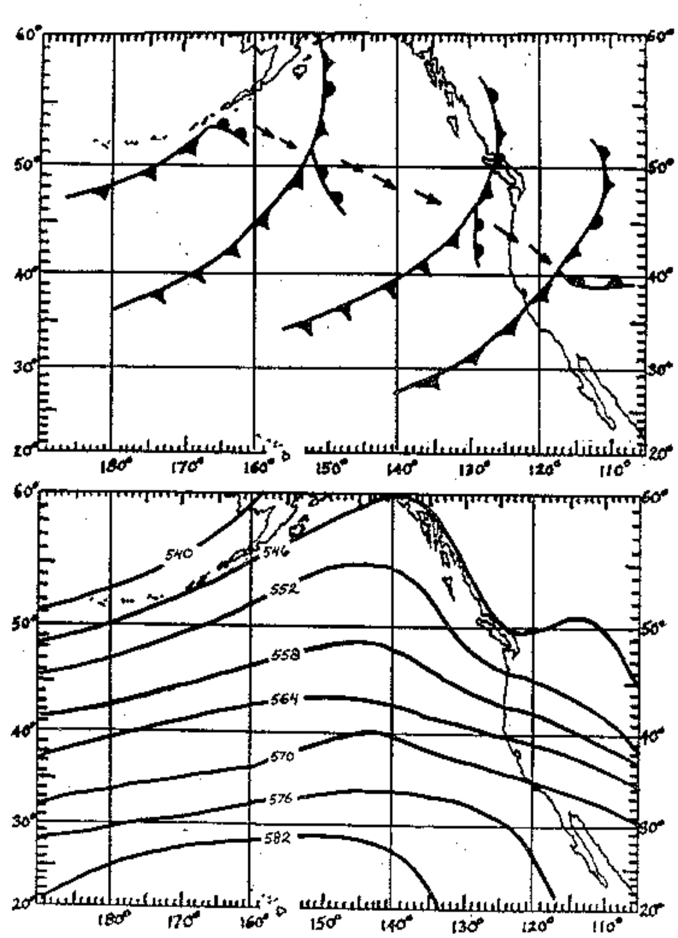
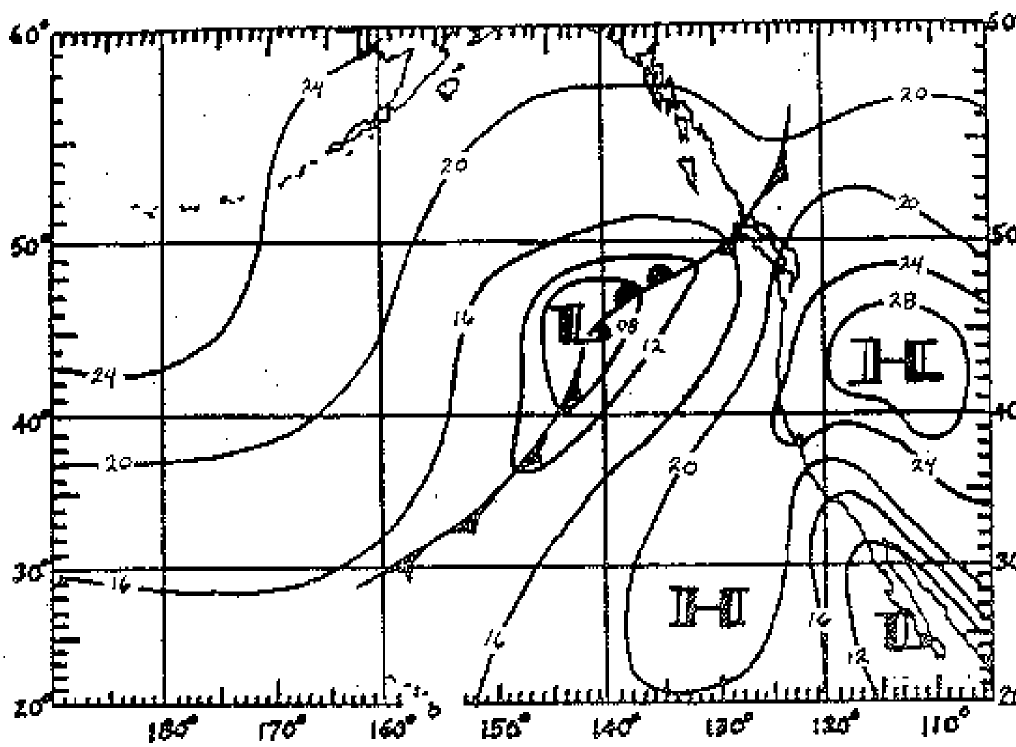


FIG. II-27 COLD FRONT APPROACHING FROM THE NORTHWEST. (NORTHERLY TYPE) II-32
FIG. II-28 TYPICAL 500MB. FLOW FOR COLD FRONT APPROACHING FROM THE NORTH.

(2) An upper cold front moves eastward over the Canadian Rockies as the surface occlusion dissipates over the Cascades and Washington mountains. A low develops in Montana or Alberta with a reactivated cold front extending southwestward through central California. Light rainshower activity can be expected in the area with little precipitation in the South Bay. Surface winds are relatively light during prefrontal conditions, but post-frontal northerly winds are gusty and erratic.

(3) A shortwave trough is embedded in the major ridge at the 500mb level (125 to 130 degrees west). As the shortwave moves southeastward, it intensifies and gives excellent support for cold frontogenesis in Utah and Nevada. Precipitation may not occur along the coast, but extensive rain and snowshower activity occurs in the Sierras.

Cyclonic storms which approach from the eastern pacific hinder air operations. These storms approach the California coast on an average of every seven days. Every fourth storm is more severe than the others and will stagnate for two or three days off the Pacific northwest coast especially when upper level troughs persist for days off the west coast of the U.S. shortwave impulses revolve around the stationary trough alternating 24 periods of rain and clearing to California. Warm occlusions or modified cold fronts are most prevalent over California.



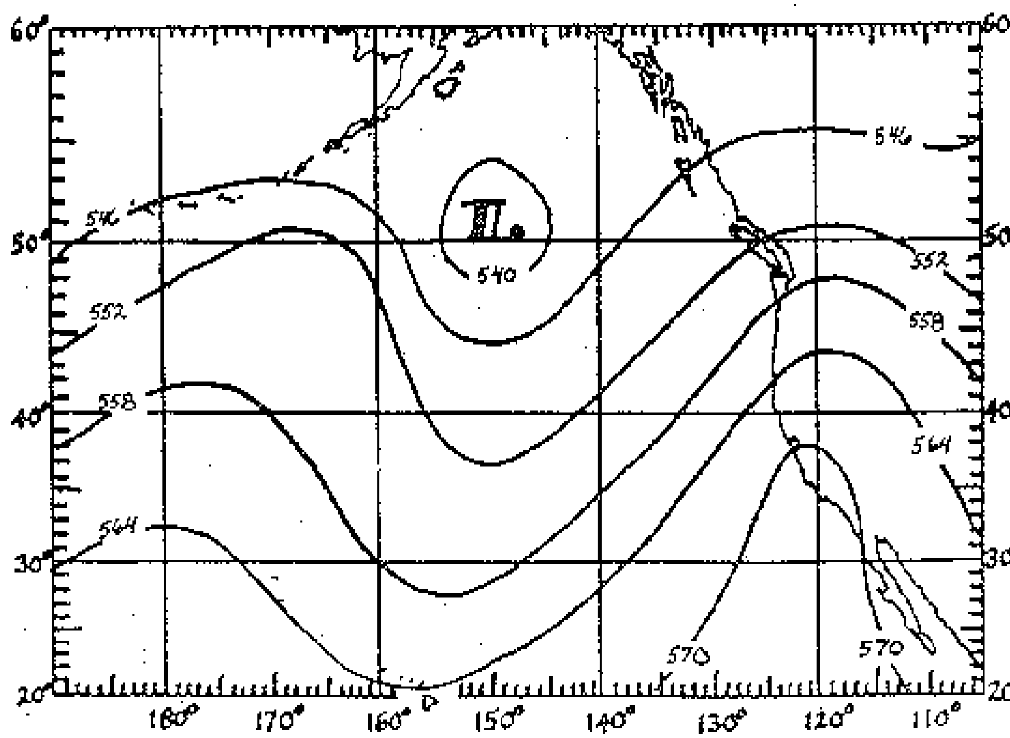


FIG. II-30 SANTA ANA SURFACE
FIG. II-31 SANTA ANA 500 MB. II-34

c. Cold Core Low Aloft. A closed low aloft centered in the area of 130 to 140 degrees west and 30 to 40 degrees north is the least common variation. It will produce very heavy rainfall in a 5-day period. Frontal activity is normally absent, but shortwave troughs moving out of this closed low (difficult to detect and track on fax charts) will approach the West Coast on an average of every 24 to 36 hours. Light to moderate precipitation usually occurs for a 12 to 18 hour period as each trough approaches the California coast. Partial clearing may be expected after the trough pass over the station. A distinct variation of this type evolves from a sharp trough that becomes a ‘cutoff low’. If the cold-core low aloft at the 500mb level forms near 125 degrees west and south of 40 degrees north, precipitation in the form of moderate rainshowers may be expected (see figure II-29). If this low progresses slowly eastward while maintaining a cold vortex of near -30 degrees Centigrade or colder, thunderstorm activity is common in the Bay Area. Associated hail is normally light and of short duration, and is more prevalent over mountainous terrain.

3. **Weather in an Occluded Front.** The usual sequence of events when an occluded front approaches the California Coast is as follows: 24 to 30 hours before it passes, or 500 to 700 miles ahead of the front, high thin cirrus and cirrostratus appear from the west or southwest. This gradually thickens and lowers into a solid altostratus cloud sheet. About 250 miles ahead of the front, or around 12 hours prior, light intermittent rain begins to fall. The rain increases gradually, with ceilings of 4000 to 5000 feet along a wide belt, which moves progressively, down the Pacific coast. Since the fronts are predominantly oriented northeast to southwest, the lowering ceilings and weather appears to move from the northeast to the southwest as the front move eastward.

Strong southerly to southeasterly winds aloft nearly always exist ahead of these fronts. Surface winds are normally strongest for the six-hour period preceding frontal passage.

Visibility will be quite variable due to precipitation and will change rapidly between 2 to 10 miles. It is well to remember that visibility measurements in such cases decrease rapidly to zero as an aircraft climbs through an overcast from which rain is falling.

Precipitation is usually heaviest just before frontal passage, the winds are gusty and the and the ceilings drop as low as 200 feet with visibilities of 2 miles for short periods. Cloud layers will merge with a solid cloud deck (nimbostratus) to 18000 feet. Icing is most prevalent above an occluded front and rime icing will completely cover the leading edges of the aircraft’s wings in less than 10 minutes. With frontal passage, the surface wind veers to the southwest and then gradually veers to the northwest.

The precipitation pattern changes to isolated shower activity lasting for several hours along the coast, but rapidly dissipates farther inland. Turbulence and icing still present a fight hazard to consider within the towering cumulus clouds. A thumb rule - actual weather is more severe along the coast than in the Sacramento or San Joaquin Valleys. Since the coastal range tends to extract part of the moisture from the clouds, ceilings and visibilities are superior in the interior. A front will usually be intensified as it moves over the Sierras. The Sierra Nevada range averages from 800 to 12000 feet in height and violent local storms can rage along the range while weather in the interior valleys remains mild.

4. **Santa Ana**. During the fall and winter the famous "Santa Ana" winds occur over southern California. Although not as dramatic in central California, the effect is present. Conditions required include ridging over Washington and Oregon with a strong east-west gradient over central and southern California. Minor departures from east to west flow are the determining factors for occurrence in the Bay Area and locations in the central valleys. These effects are occasionally felt at Moffett Field with north to northeast winds gusting 25 to 30 knots. The effect is usually transitory and may only last 30 minutes as minor changes in the general flow move past the field. However, locations on the eastern side of Santa Clara valley below passes and canyons feel strong effects. This is of great significance to all small aircraft in the area and also large aircraft departing the airfield to the south and east.

In California's Central Valley, the effect normally occurs while the general flow is northeasterly enhancing surface winds on the extreme western side of the San Joaquin valley while not being present at locations on the central and eastern side of the valley. The condition is characterized by the above synoptic situation and also warmer than normal temperatures, very low dewpoints and clear skies accompanied by exceptional visibility. Figures II-30 and II-31 depict the typical situations at the surface and 500mb levels, which are favorable for Santa Ana conditions.

5. **Stratus.** The major summer weather problem from the standpoint of flight operations is the persistent stratus layer that advects over the field during the late evening hours. During the summer season the surface pressure pattern becomes almost static with an eastern Pacific high pressure cell centered to the west or northwest of the San Francisco Bay area and a thermal low pressure trough persisting over the interior deserts and inland valleys. This synoptic pattern favors the advection of stratus over the coastal regions and nearby bays and inlets. (See figures II-32 and II-33).

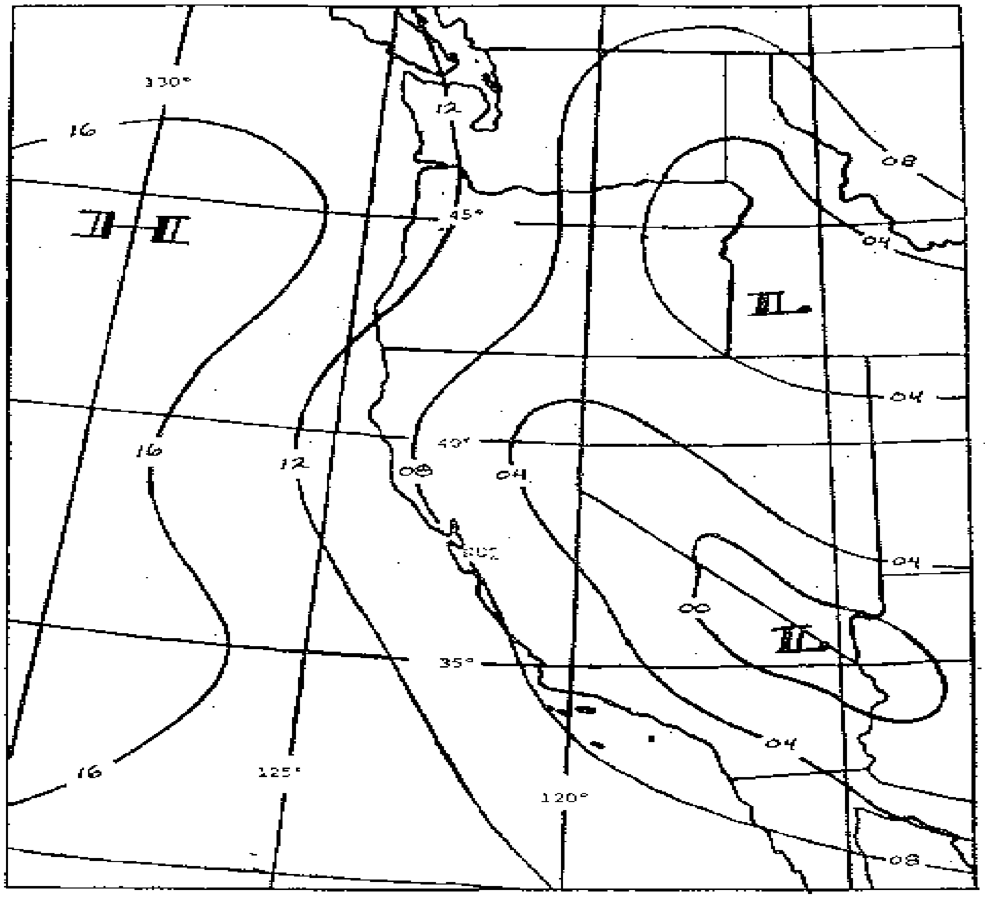


FIG. II-33 PATTERN FAVORABLE FOR STRATUS ON ENTIRE CALIFORNIA COAST

II-38

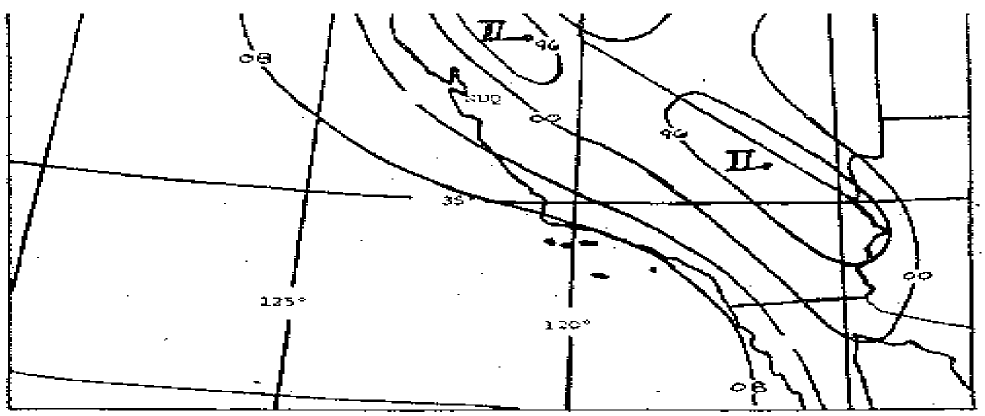


FIG. II-32 TYPICAL PRESSURE PATTERN FAVORABLE FOR STRATUS ON CALIFORNIA COAST NORTH OF POINT ARGUELLO.

II-37

The stratus is primarily brought about by an onshore flow of moist maritime air beneath a temperature inversion associated with the eastern edge of the Pacific anticyclone. The entire coastal region of California is an area or marked subsidence caused by the anticyclonic flow of the Pacific high, and augmented by periodic ridging aloft at the 850mb and the 700mb levels. This subsidence is a significant factor in governing the formation of stratus by creating a temperature inversion above the surface strata.

The altitude of the inversion is subject to both diurnal variations and variations caused by fluctuations in the degree of subsidence. The diurnal variation corresponds to an increase in height during the night, to a maximum of approximately 3500 feet at sunrise, and a decrease in height during the day, to a minimum of approximately 1000 feet in the late afternoon. The variations caused by fluctuations in the degree of subsidence are a direct result of the strength or intensity of the high-pressure ridge, and also it’s position. If the ridge increases in strength or is centered more directly over the area, then the base of the inversion will be lower. The diurnal changes of the bases of the stratus are opposite to the inversion fluctuations. The height of the bases lower during the night because of the thickening clouds associated with cooling of moist stratum. During the day the height of the bases increases because of daytime heating.

Stratus may move into the bay and the Santa Clara valley at almost any time after sunset, but the usual appearance at Moffett Field occurs near midnight and continues until mid-morning. During the summer a cloud deck may be observed spilling over the edge of the coastal mountains to the west in the early evening. The major inflow of stratus into the south end of the bay is through the San Francisco gap (west of the San Francisco airport) and the Golden Gate. However, when the inversion is relatively high, the stratus will advect over the mountains to the west of Moffett Field. Occasionally the stratus will approach the field from the south. The conditions favorable for this are southerly winds below 5000 feet and a relatively low inversion height with an extensive stratus deck over Monterey Bay.

6. **Fog**.

a. General. Winter radiation fog accounts for approximately 65% of the winter IFR conditions and most of the below GCA minimum conditions. Radiation fog shows an increasing tendency to occur anytime after September, but the main season is November through February. The winter fog at M.F.A. is primarily classified as a high inversion type radiation fog, but frequently, it is actually a combination of advection and radiation fogs. It is common for fog to form over the bay waters just to the northeast of the station or in the lower parts of the Santa Clara Valley, and then drift in patches over the field.

Radiational fog, when it forms locally, usually occurs during periods between frontal passages, and is not associated with any frontal synoptic condition. The most common period for radiation fog is approximately three days after a frontal passage. The maritime polar air mass over the area begins to stagnate and subside with the moisture effectively trapped by a subsidence inversion. Once formed, radiation fog conditions may persist for several days forming near midnight and clearing around midday. Occasionally the fog layer is thick enough to persist throughout the day. There are periods on record of fog conditions persisting for five days without dissipation, but this situation is considered a rarity. Frontal fog conditions occur infrequently.

b. Cause - Description. Fog occurs when the surface strata of the atmosphere has acquired an abnormal amount of moisture or a decrease in temperature. Moisture is gained by rain falling through the lower layers (evaporation), or it is provided by the onshore flow of maritime air. The temperature decreases through radiational cooling with maximum cooling in the shallow layer (50mb) nearest the surface. In the southern part of the San Francisco Bay and Santa Clara Valley, this cooling is augmented by the nocturnal cold air drainage along the slopes of the Diablo Range and Santa Cruz Mountains.

The existence of a temperature inversion usually occurs with fog. The thicker the layer above the surface through which the inversion is found, the more favorable it is for fog formation. This is especially true if there is also a moisture inversion. Fog most consistently occurs in the South Bay area if a sharp temperature inversion persists just above a shallow moist surface layer with comparatively drier air aloft.

D. Local Climatology.

Data in this section has been extracted from the Percentage and Frequency Summaries of Monthly Meteorological Records for NAS Moffett Field prepared by NMOCD Asheville, NC dated April 1983. The information is based on the period March 1945 to December 1982 inclusive. Although applicable to much of the local area, many elements for which frequencies and averages are listed should be construed as being representative of M.F.A. and not at other locations within the local forecasting area, as previously defined.

1. **Sky Cover**. There are two concise periods during which a maximum of clear days (24 hour periods) occur in this locality. The peak percentage of clear days is during the transitional months of March and October. Clear days are most numerous during the spring between the time the normal trajectory of storms is shifted to the north of the local area and the onset of the summer stratus regime. A secondary maximum of clear days is experienced in the fall between the time that the stratus regime ends and the storms trajectories shift southward to the latitudes of the Bay Area. Clear weather in the summertime is normally limited to interruptions of the established stratus regime (see Stratus).

During the winter months, clear weather is most often observed following cold frontal passage and after the gradient winds aloft shift to the northwest. Depending on the time lapse between frontal passages and the intensity of subsidence caused from ridging aloft, clear days ensue for an average of two to three days. Generally, wintertime clear days are the result of a northwesterly flow, or fresh offshore flow from modified maritime air from an anticyclone centered over the northwest. This will cause a northeasterly flow of comparatively dry air in the Bay Area. Clear weather lasts as long as these favorable conditions persist, but subsequent air mass modification and the return of a subsidence inversion may result in radiation fog. (See table II-34 for Sky Cover percentage).

Sky Cover Percentage of occurrence (Table II-34)

Month	0 - 1/8	2/8 - 7/8	8/8

JAN	19.1	47.1	33.8
FEB	11.4	53.2	35.4
MAR	15.6	51.4	33.0
APR	24.9	54.4	20.7
MAY	31.1	54.0	14.9
JUN	36.1	49.5	14.4
JUL	46.7	39.7	13.6
AUG	39.9	44.7	15.4
SEP	40.9	41.1	18.0
OCT	34.1	47.4	18.5
NOV	20.8	53.2	26.0
DEC	22.3	47.9	29.8
AVERAGES	28.6	48.6	22.8

2. **Visibility.** Winter radiation fig is the major cause of low visibilities in the South Bay area. November through February average 88 hours per month when the visibility is less than 3 miles and average 33 hours a month visibilities of 1 mile or less. Radiation fog occurs most frequently in December with the visibility 3 miles or less, more than 17% of the time. Radiation fog that forms over the bay waters north of the field in patches causing visibility to vary between 0 and 2 miles.

Due to the concentration of industrial and commercial enterprises along the South Bay shores and Santa Clara Valley, haze/smoke may cause the visibility to remain below 3 miles when there is high pressure ridging over the station at the 700mb and 850mb levels with relatively calm surface winds. This condition is possible any time during the year. Smoke and haze will be evident during periods of comparably dry air with a marked subsidence inversion just above the surface strata. Tables II-35 and II-36 present monthly percentages of occurrence of haze/smoke and fog with hours of maximum frequency. Table II-37 represents the percentage of days with smoke/haze and fog. Table II-38 shows by month percentage frequency of ceiling Vs. Visibility. March through June have the best flying conditions with December having the worst.

Hours of Frequency
% Haze and Smoke
(Table II-35)

Month	Time	Avg %
JAN	07-23	0.6
FEB	07-15	27.5
MAR	07-14	13.4
APR	07-14	13.1
MAY	07-14	19.5

Hours of Frequency
Fog
(Table II-36)

Month	Hours	Avg %
JAN	00-11	19.5
FEB	03-11	14.0
MAR	07-11	6.6
APR	04-08	3.5
MAY	04-07	2.6

JUN	07-14	19.1	JUN	04-07	5.7
JUL	07-14	26.9	JUL	04-07	9.7
AUG	07-14	24.0	AUG	04-07	11.3
SEP	07-14	34.4	SEP	04-07	16.7
OCT	07-17	31.9	OCT	01-07	13.9
NOV	10-17	29.9	NOV	01-11	16.5
DEC	10-22	39.7	DEC	01-10	27.0

Percent of Days With
Smoke/Haze and Fog
(Table II-37)

Month	Smoke/ Haze	Fog
JAN	53.1	43.1
FEB	45.4	34.7
MAR	30.9	14.3
APR	31.8	12.3
MAY	34.0	8.8
JUN	35.0	7.5
JUL	58.5	17.4
AUG	59.0	22.7
SEP	60.4	24.5
OCT	58.2	30.9
NOV	55.8	38.4
DEC	57.2	48.9
ANNUAL	48.3	25.3

Ceiling Vs. Visibility
% of Frequency VFR Minimums and Below
(Table II-38)

Month	1000/3	300/1	100/ 1/4
JAN	9.4	2.0	0.8
FEB	6.4	1.4	0.5
MAR	0.8	0.2	0.1
APR	0.2	0	0
MAY	1.0	0	0
JUN	1.4	0	0
JUL	5.1	0	0
AUG	4.1	0	0
SEP	5.4	0	0
OCT	7.1	0.7	0.2
NOV	6.6	1.5	0.6
DEC	17.7	3.8	1.9
ANNUAL	5.6	0.8	0.3

3. **Ceiling.** During the winter low ceilings are the results of migratory frontal activity or radiation fog low ceilings associated with frontal disturbances do not affect the station for periods other than the normal sequence of frontal passage. The Diablo range to the east of the field is not high enough to perceptibly block normal storm movement. This is not true of the general area. Regions to the North, East and South of M.F.A. undergo prolonged periods of bad weather due to the storm blocking effect of the mountainous terrain. During the winter season fronts will sometimes become quasi-stationary and prolong low ceilings over the Sierras, Cascades and coastal ranges.

Winter fog is responsible for about 65% of the winter IFR conditions. Indefinite low ceilings come about as the fog lifts and are lower than either frontal or stratus caused ceilings. Summertime stratus is responsible for 95% of the summer IFR conditions. This cloud layer, commonly called coastal stratus, may occur during any season but is most frequently observed from May to October. The resulting low ceilings occur most frequently from midnight to mid-morning.

4. **Precipitation.** Precipitation at M.F.A., with the exception of drizzle experienced occasionally with summertime stratus or showers associated with infrequent thunderstorm activity, occurs during the winter months (see table II-39). Graph II-40 depicts percentage of days with rain and/or drizzle at M.F.A. During the summer the Eastern Pacific High is displaced

RAIN AND / OR DRIZZLE

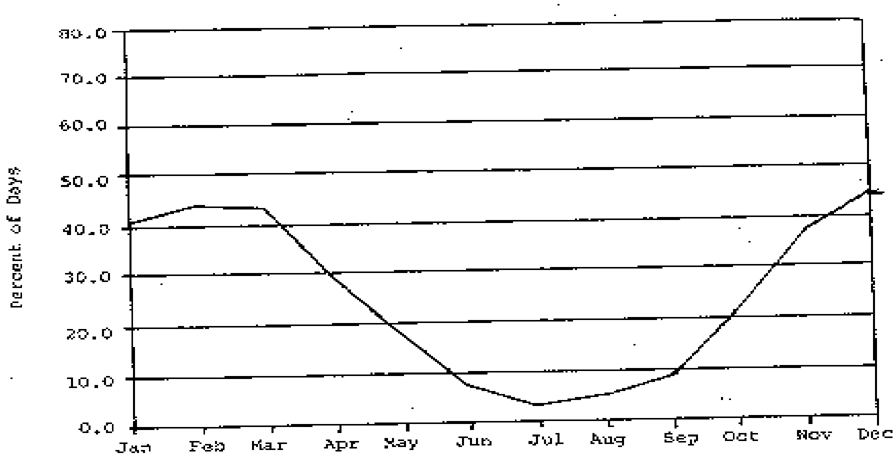


FIG. II-40

II-43

northward and storm tracks are normally steered north of California. In October the Pacific High recedes southwestward, and storm systems track to a more southerly latitude.

These storms gradually become more intense with the most severe storms occurring December through February. During March and April the storm routes gradually move northward again. Frontal effects experienced during the early and late winter months are caused principally by trailing fronts associated with low-pressure centers to the north. The maximum rainfall is reached during the months of the most southerly storm trajectory. An occluded front moving in from the west usually will produce .5 to 1.0 inch of rain in a 36-hour period, whereas the precipitation from a cold front approaching from the north is somewhat less. The most precipitation in any three-day period can be expected from a 'cold core' low aloft positioned west of the California coast.

Monthly Precipitation
(Table II-39)

Month Year	Max	Mean	Min	24 HR Extreme
JAN 1982	6.81	2.89	.22	2.70
FEB 1986	7.66	2.09	.09	1.67
MAR 1982	5.95	2.03	.07	1.32
APR 1958	3.98	.95	.01	1.17
MAY 1956	1.74	.34	0	.68
JUN 1964	.46	.08	0	.37
JUL 1980	.47	.04	0	.41
AUG 1975	.64	.05	0	.53
SEP 1959	1.98	.17	0	1.96
OCT 1962	3.52	.73	0	2.51
NOV 1970	5.58	1.74	T	2.78
DEC	9.55	2.35	.15	2.23

Occasionally, freezing and frozen precipitation occur at M.F.A. There have been five instances of snowfall at this station with the only appreciable snowfall occurring on 21 January 1962 when 1.8 inches of snow was recorded.
However, it's not uncommon for appreciable amounts of snow to fall in the mountains and hills

surrounding the Santa Clara Valley at or above the 3000-foot level.

5. **Temperature.** The coldest months of the year are December, January and February, when the mean temperature is in the forties (see graph II-41). Below freezing temperatures are common during these months. The lowest temperatures usually result from an outbreak of Arctic air moves down from the Pacific Northwest and over the Rocky Mountains. The resulting high pressure cell over the northwestern United States creates a northerly flow of cold, dry air over the area. Relatively clear skies exist during this synoptic situation, and nighttime radiational cooling patterns are not hampered. Consequently, the second and third nights during such an influx of continental modified air result in low temperatures. The lowest temperature recorded at M.F.A. was 21 degrees F. in January 1949. Conversely, moist maritime air tends to keep winter temperature higher.

The maximum temperatures are reached in June through September with the mean temperature remaining above 63 degrees. There is a definite increase in the daily mean maximum during the early fall. The highest temperature recorded at M.F.A. was 105 degrees in September 1971. (See appendix 1 for a case study of this occurrence). The highest temperatures usually occur during periods of weak sea breeze and ridging aloft. This situation occurs during spring and fall when an influx of colder air moves over the Pacific Northwest from the Gulf of Alaska. The resulting high-pressure creates a flow of warm, dry air from Nevada and the interior valleys of California, offsetting the normal cooling effects of the afternoon sea breezes. There is also maximum radiational cooling during the summer and early autumn, and the greatest variance between maximum and minimum temperatures usually occurs during these periods.

6. **Thunderstorms.** Thunderstorms occur in the Bay Area both during the summer and winter. The more frequent activity occurs in the winter and early spring when cumulonimbus clouds are associated with unstable, fast-moving cold fronts. Thunderstorm activity may also occur in an air mass associated with a 'cold core' upper level low. The vertical air structure is cold, moist and conditionally unstable with a low freezing level.

When a trough sets up west of California bringing an unstable upper level southerly flow over the area, the possibility of thunderstorms exists. If this southerly flow is accompanied by a low off the southern California coast, moist tropical air is brought in, creating yet another triggering mechanism. The stability index on the Oakland sounding should be closely watched at these times. Methods of re-computing the stability index from the Oakland sounding are available and should be used during this situation to provide an accurate picture of the atmosphere in the South Bay area.

During hurricane season, the remnants of a hurricane will set up as a low situated south of the San Diego area. As the low moves closer to land, it creates enough instability to bring thunderstorms to the Diablos and occasionally to the local coastal waters, seldom invading M.F.A.

Individual thunderstorms have been recorded at almost any time from March through October, with the latest being Mid-July 1990. During periods of unstable air, cumuliform buildups may be noted over the mountains surrounding the southern and eastern sides of the Santa Clara Valley seldom moving over the field.

SECTION III - FORECASTING

A. ***Subjective Rules***

1. **Summer Stratus.**

a. Consider the coastal area from Portland Oregon to Santa Maria California on the 0600Z surface weather map. When the flow of the eastern edge of the Pacific high turns sharply cyclonic just off the northern California coast (within 200 miles offshore) and that flow becomes west to east in the vicinity of Half Moon Bay to the Golden Gate, stratus will occur at Moffett Field during the 18 hour period beginning at noon (LST) the following day. When the cyclonic flow is displaced southward so that the west to east flow occurs near Monterey, stratus will occur at Moffett Field with the cloud deck approaching from the southwest. This rule is quite subjective since it depends on the accuracy of the surface analysis, the estimation of the airflow trajectory from surface to 2000 feet, and the trend in stream flow. Since pressure patterns change very slowly during the summer season, comparing the synoptic pattern of the previous 24 hours with that of the forecast for the next 24 to 36 hours, the forecaster can determine if the flow is conducive to stratus formation.

b. The following conditions are conducive for the initial formation of stratus along the central California coast: the Pacific high located west or northwest of the Bay Area, the thermal trough extended into the interior valleys east of Moffett Field, and moist onshore flow with a low level subsidence inversion present.

c. The onset of a stratus deck advected over Moffett Field is usually midnight.

d. Stratus can be expected to advect over the field earlier than normal when the following conditions exist: (1) The inversion height is increasing, or higher than 3500 feet. (2) Horizontal convergence occurs below the inversion level (cyclonic flow in the surface stratum along the coastal regions between Pt. Reyes and Monterey Bay). (3) Relatively strong westerly or southwesterly winds at the 2000 to 3000 foot levels.

e. Stratus can be expected later than normal when the inversion height is lower than 1000 feet and the anticyclonic flow parallels the coastline.

f. Forecast a summer stratus dissipation rate of 350 feet thickness per hour if no upper clouds are present and an accurate report of the top of the overcast is available. This rule is reliable when tops of the stratus overcast are below 2500 feet and thickness is less than 2000 feet. When tops of the overcast are 1500 feet or less, use a dissipation rate of 400 feet thickness per hour.

g. When the wind (surface to 850mb) is from the north to northeast in the late afternoon and early evening, a stratus layer will not occur over Moffett Field during the evening or next morning.

h. Once the stratus regime has been established, forecast persistence of night and morning stratus unless ridging is expected over Washington or Oregon.

i. When southerly flow is present aloft and the cloud thickness is greater than 2000 feet, expect light drizzle of short duration in the early morning.

2. **Fog.**

a. The following conditions favor fog formation at Moffett Field: (1) Existence of fog the previous evening or morning. (2) Less than six knots of wind. (3) Relatively clear skies. (4) High moisture content in the surface strata, especially the first 100mb. (5) The more stable the hydro-lapse rate in the first 150mb, the greater the chance of fog.

b. Fog may be expected at Moffett Field when minimum temperatures of 50 degrees are expected and the following conditions exist: (1) An occluded front is approaching the coast. (2) A very shallow layer of cool air exists in the Bay Area, originating from an anticyclone centered to the northeast. (3) Prefrontal light southwesterly winds override the shallow layer of cool air.

3. **Precipitation**.

a. If the occluded portion of a frontal system remains to the north of San Francisco, and relatively colder air occupies the coastal valleys, air coming in from the Pacific behind the cold front is force aloft. The resulting precipitation varies from light rainshowers to intermittent light rain.

b. During the winter when the 500mb 5640 isoheight line is forecast to be over or in the vicinity of the Bay Area and there is a cold front approaching the area from the west or northwest, forecast rain at Moffett Field. This rule works fairly well with fronts, but does not handle the cutoff low with any degree of success.

c. Southwesterly flow aloft during the transition season should be considered as an advance indication of rainshowers within 24 hours.

4. **Wind.**

a. During the winter west to southwest low-level wind flow over the Santa Cruz mountains will create a modified foehn effect in the south end of the bay and Santa Clara Valley. This will cause accelerated dissipation of low clouds following frontal passage.

b. Surface winds rarely prevail from the west through southwest or from the northeast through east. When the gradient flow over the immediate coast and south end of the bay is east through southwest, the surface wind at Moffett Field will be southeasterly.

c. With a relatively weak southwesterly gradient flow offshore and over the central California coast and interior valleys, the winds at Moffett Field will be northwesterly in the late afternoon and shift to light southeasterly by late evening.

d. The following procedure can be used to forecast maximum wind gusts about 75% of the time: If the 1200Z Oakland sounding indicates winds of 30 knots or greater at the 925mb level and is expected to persist, forecast a maximum gust of 3 knots less than the highest wind on the sounding at that level. An assumption is made that the winds are from the west through north at or just above the inversion level. The gusts should be forecast when the inversion breaks due to daytime surface heating.

5. **Forecasting From Satellite Data**. Satellite imagery can be a useful tool to the forecaster in supplementing conventional observations as well as providing information when other data is not available. Location of fronts, troughs and ridges as well as interpretation of more localized weather phenomena can be made less difficult by utilizing satellite imagery. The following phenomena can be easily forecast by using satellite imagery:

a. Stratus and Fog. From previous forecasting data in this handbook, it is understood how difficult forecasting stratus and fog formation and dissipation can be. By interpreting and utilizing satellite imagery the forecaster the forecaster can make a more accurate forecast. Some specifics for identifying stratus and fog are: (1) From satellite photos stratus and fog appears flat, often with sharp edges and patterns conforming to topographical features, especially along the coast and in the central valleys of California. (2) Thin stratus or fog will appear grey while thick stratus and fog will have a brighter appearance. (3) At times when higher clouds are present shadows which are cast will give a non-uniform appearance. Due to the distance between the low cloud tops and the upper clouds, these shadows are usually large and distinct. (4) During the winter when the central California valleys are experiencing dense "Tule" fog, the extent is readily discernable from satellite imagery.

b. Turbulence. Studying recent satellite photos along with the current surface and upper air analysis can prove invaluable in determining areas of turbulence as well as intensity. Cloud types and location can be associated with different aspects of turbulence.

(1) Lenticular clouds and wave patterns are indicative of orographically induced turbulence. (e.g., mountain waves).

(2) Jetstream cirrus indicates area of turbulence induced by strong horizontal shear in the upper troposphere. Moderate or greater turbulence is more often associated with dense overcast jet stream cirrus than with thin or scattered cirrus.

(3) Certain convective cloud forms indicate the strength and relative depth of turbulent convection. Cumulus and towering cumulus, having a certain lumpy, uneven textured appearance on satellite photos, indicate regions of light to moderate turbulence. Cumulonimbus clouds appearing as individual cells or in clusters indicate areas of moderate to severe turbulence. Turbulence associated with cumulonimbus is not restricted to the cloud, but can occur in the clear air around the cloud and as much as 500 feet above a developing CB.

(4) Other features such as fronts, developing frontal waves and areas of positive vorticity advection (PVA) maxima have distinctive cloud formations associated with areas of turbulence. The frontal band as a whole should be considered when forecasting

turbulence, especially areas where embedded convective activity is a probability. With a developing frontal wave and an 'attentive' jet stream, there is frequently a large area of significant turbulence through a thick layer of clouds. Turbulence below 20000 feet is usually associated with frontal clouds, while turbulence above is related to the jet stream. In PVA maxima, turbulence is most often associated with the northeast quadrant of the maxima.

c. A more detailed explanation for using satellite imagery in forecasting for various weather phenomena can be found in the following publications: Technical Report 212; Direct Transmission System User's Guide; Guide for Observing the Environment With Satellite Imagery; NWRF F-0970-158; and Guide for Interpretation of Satellite Photography and Nephanalysis, NAVAIRSYSCOM, Project FAMOS.

B. Objective Rules.

1. Stratus Dissipation.

a. Daily dissipation results primarily from solar insolation rather than a change in circulation or air mass. The dissipation rate shown by figure III-1 has been found to be fairly reliable from June through September. This graph is similar to Steffan and Morgan's 'Solar Insolation Graph' (1945), which has been modified for the Moffett Federal Airfield area. The graph determines the time when a stratus overcast becomes broken with complete dissipation (clear to scattered) occurring one hour later.

b. Dissipation will be faster than the rate indicated when:

(1) A downward trend in the height of the inversion for over 24 hours or longer is indicated.

(2) An upward trend in the 700mb and 850mb heights indicating increased subsidence is noted.

(3) And a lower than normal stratus base exists (below 600 feet).

c. Dissipation will be slower than the rate indicated when:

(1) An upward trend or higher than normal inversion height over 24 hours or no longer exists.

(2) a downward trend in the 700mb and 850mb heights exist (troughing approaching the coast.

(3) increased advection or onshore flow exists and is reinforced cyclonic circulation around intense thermal troughing extended north into the Sacramento area.

d. On rare occasions during the summer, all the conditions favoring a slower dissipation rate will cause stratus ceilings to persist through the day. The bases will increase gradually through the day and lower again at night.

2. **Fog Formation.**

a. A radiation fog forecasting nomogram, originally constructed in 1917 by C.F. Taylor has been modified for use at M.F.A.. The nomogram (figure III-2) has been proven to be quite accurate. The nomogram utilizes ordinates of dewpoint depression and abscissa of temperature at 1800L. Conditions for the use of the radiation nomogram follow:

(1) No low clouds present or expected.
(2) Clear to high thin broken clouds (No ceilings).
(3) No frontal conditions expected to influence the area by the following morning.
(4) Surface winds less than six knots at 1800L and relatively calm conditions expected through the night. Wind acceleration is important. If wind speeds increase moderately during the late afternoon and early evening, the formation of fog will be unlikely, greatly retarded, or will form as a low stratus ceiling.

b. Under the following conditions the nomogram may be used as a guide, but with reservations:

(1) Scattered to thin broken middle clouds but not frontally associated are present or forecasted.
(2) when the wind speed at 1800L is less that 10 knots and is expected to become light and variable. In this case, fog may form in the upper bay regions, but due to turbulent mixing, the fog will lift to a definite stratus ceiling as it advects southward.

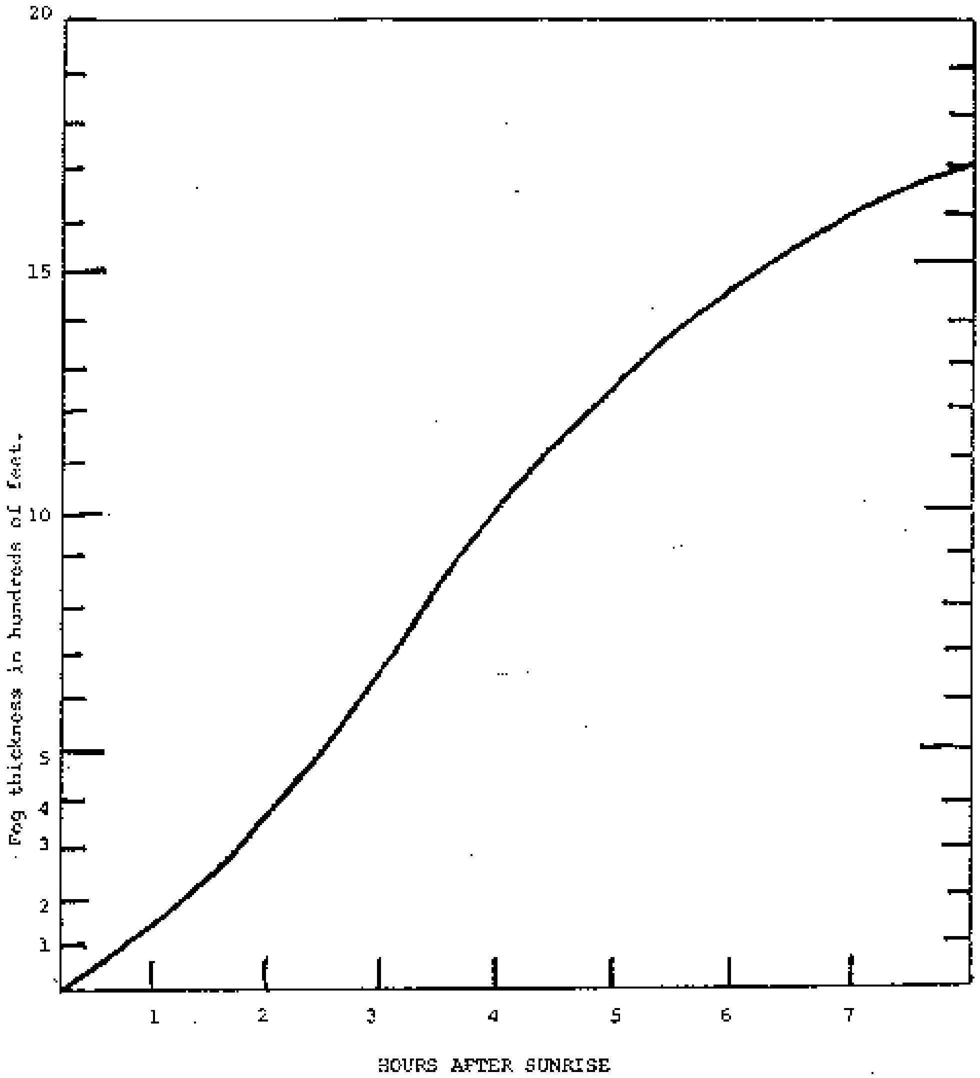
c. At present no workable means has been determined to enable the M.F.A. forecaster to accurately predict the time of fog formation when conditions are favorable and indicated by the nomogram shown in figure III-2. Fog will usually form by midnight whenever the 1800L temperature is 55 deg F. or less, with a dewpoint depression of less than six degrees.

3. **<u>Fog Dissipation</u>**.

a. The amount of time required for lifting and or dissipation of fog is closely associated with the following: the mean humidity in the lowest 50mb, and the characters of hydro-lapse and the temperature lapse. The lack of a M.F.A. U/A sounding necessitates the use of averages in determining the dissipation of fog.

b. Radiation fog dissipation may be determined by the use of the nomogram shown in figure III-3. The nomogram is based on an average wintertime solar insolation rate with coordinates for fog thickness and hours required to dissipate. The dissipation verification is for partial obscuration or clear skies and visibility greater than one mile. Conditions for use are:

(1) No upper clouds present or expected. (Nomogram is no good if higher clouds are present, particularly a mid cloud deck).



Dissipation of Fog ceiling to partial obscuration and visibility greater than 1 mile.

Conditions: No upper clouds.

FIG. III-3

III-8

(2) And the thickness of the fog layer should be verified by at least two top reports within a short time.

c. Dissipation faster than indicated by the nomogram can be expected when the following conditions occur:

(1) Oakland's 1200Z winds at 2000 and 3000 feet are northwest to northeast and greater than 20 knots.
(2) Surface winds from the southeast accelerate above 8 knots.
(3) And a persistent downward trend in the surface pressure exists (reflecting air warmed by subsidence aloft) and associated with a downward trend in the inversion height.

C. Special Features.

1. **Thunderstorms.** The frequency of thunderstorms in the Bay Area is low. They are associated with one of the four following situations:

a. A cold-core cutoff low aloft located offshore central California.

b. A strong fast-moving cold front.

c. An unstable wave developing off the California coast.

d. Warm, moist tropical air from the Gulf of Mexico advected around the western side of an upper level ridge.

Situations (a) through (c), are by far the most common and usually occur from late fall to early spring. Situation (d) is very rare and occurs during the summer months. This type affects the southern deserts of California and the Sierra Nevada, and rarely spreads as far north as the Bay Area.

Forecasters must always consider mechanical indications (refer to the latest sounding) to determine the possibility of thunderstorm activity and probable severity. Indications of such isolated storms present in the Hollister, Salinas and Gilroy areas may be noted from the remarks sections of hourly observations. When this type storm moves into the Santa Clara Valley, it generally enters the southern extremities of the valley. As it approaches Moffett from the south, it is usually readily discernible at some distance from the station both visually and by NEXRAD radar.

For forecasting thunderstorms, local forecasters have found that the Showalter Stability Index, K-Index and Lifted Index are good predictors for thunderstorm forecasting. The following minimum limits work well in this area:

K-Index ------------- equal to or less than 3

Lifted Index -------- equal to or greater than 28

Showalter Stability Index (Low Base Thunderstorms): (1) Equal to or less than +3, showers are probable and isolated thunderstorms can be expected in the vicinity. (2) +2 to -2, high thunderstorm probability. (3) -3 or less, severe thunderstorms can be expected.

The National Weather Service transmits a four panel stability chart twice a day which includes the Lifted Index for selected stations throughout CONUS. The forecaster must analyze the Skew-T Diagram to find the Showalter Stability Index.

Computing Stability Index for High Base Thunderstorms. Using the 00Z/12Z Oakland sounding: (1) Locate the maritime boundary. (2) select the layer above the maritime boundary where moisture is being advected into the Bay Area (at or near 700mb or 500mb). (3) Once mid-level moisture has been selected, compute the CCL/LCL, in the same manner as computing the Showalter Index, lifting a parcel moist adiabatically to 300mb.

The 1200Z sounding will need to be modified to reflect afternoon/evening meteorological conditions (i.e., morning inversions mixed down to the surface, temperature/dewpoint curves enhanced to reflect WAA/CAA or moisture advection). The 6.7um water vapor imagery from GOES is coincident to the 580mb to 300mb layer and can provide a qualitative measure of moisture to apply to sounding modification.

Upon determining thunderstorms will be forecasted, bear in mind that bases will generally lower due to evaporational cooling as precipitation falls from activity.

Lessons Learned: High Base Thunderstorms 16 July 1990, this day brought rare summertime thunderstorms to the Bay Area. Convection began over extreme southern sections near Moffett Field and San Jose and moved northeastward. Sounding data from that morning appeared innocuous at best with a SI of +9 computed from the Oakland sounding (figure III-4 shows the NEDS Skew-T). The MWA issued at 0300L from Global Weather Central did not indicate thunderstorm development in the Bay Area, but did along the Sierras. The FPUS3 issued at 0300L by the National Weather Service in San Francisco mentioned thunderstorm activity, however further south and not in the bay. If the described method of computing the Stability Index for high base thunderstorms had been available and used, a SI of +3 would have been computed. After additional modification for moisture, a SI of near 0 may have been depicted. A somewhat less stable sounding.

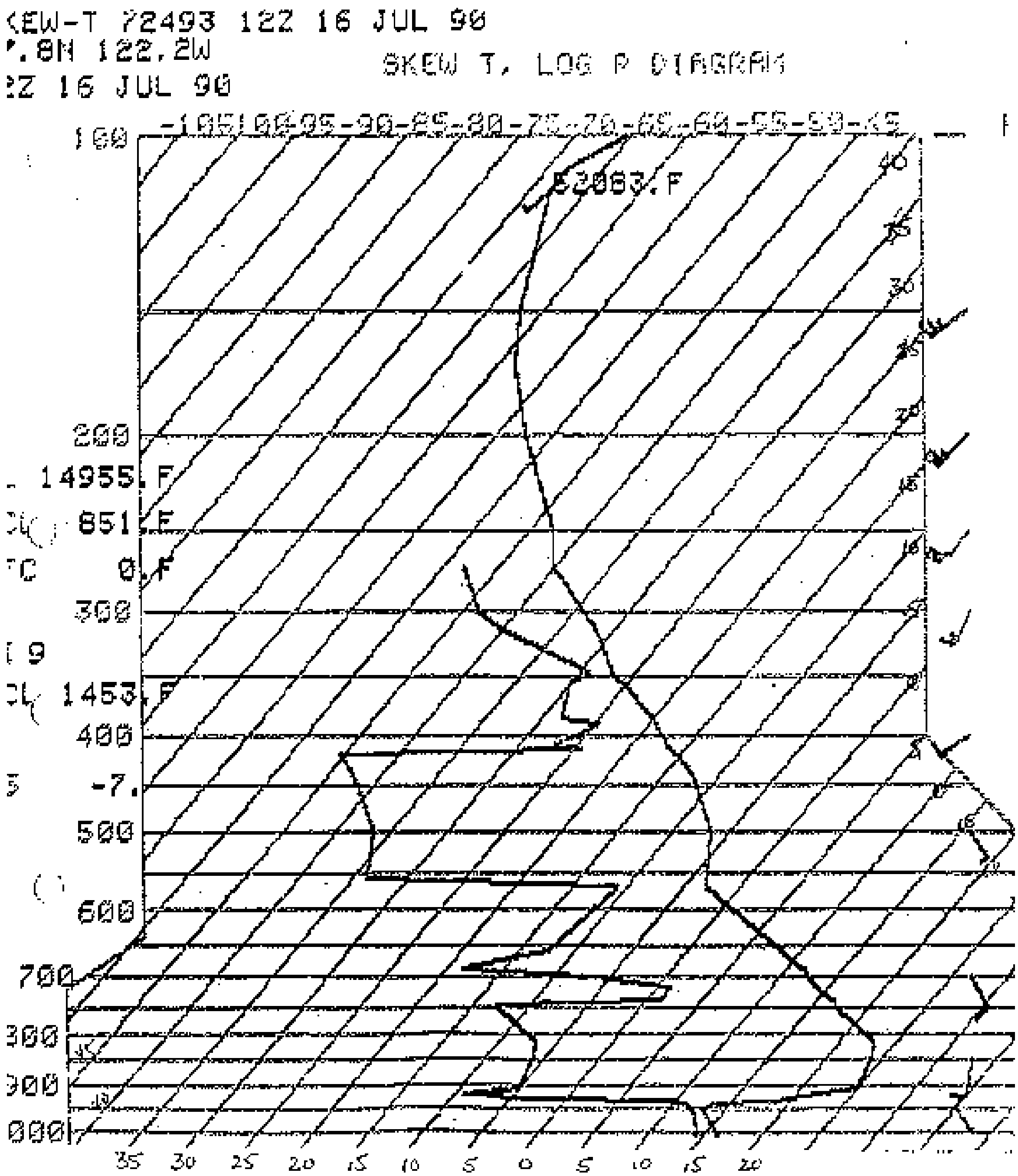


FIG III-4

III-10

Procedures for computing the Showalter Stability Index can be found in the AG1+C, and in NAVAIR 50-IP-5 (Skew-T, Log-P Diagram in Analysis and Forecasting). In any potential thunderstorm situation, the forecaster needs to determine if adequate moisture exists. The National Weather Service four panel stability chart provides moisture content information. One panel presents precipitable water from surface to 300mb, another, relative humidity. Reasonable values conductive for thunderstorm development are .70 inches or greater for precipitable water and 80% relative humidity or greater.

2. **Icing.** During the summer icing problems are non-existent since the freezing level is above 10000 feet. In the winter the average freezing level drops to 4000 feet at Eureka, 6000 feet at San Francisco and 7000 feet at Santa Maria. In stratus type clouds of stable air masses, the icing rate is very low and presents no serious problems. Moderate rime icing will usually be encountered in prefrontal cloud decks laden with moisture. Icing will be severe in cumulus cloud developments in an area of frontal activity. In frontal systems the freezing level will normally lower to 3000 feet in the Bay Area and severe icing may be encountered up to 14000 feet. Figure

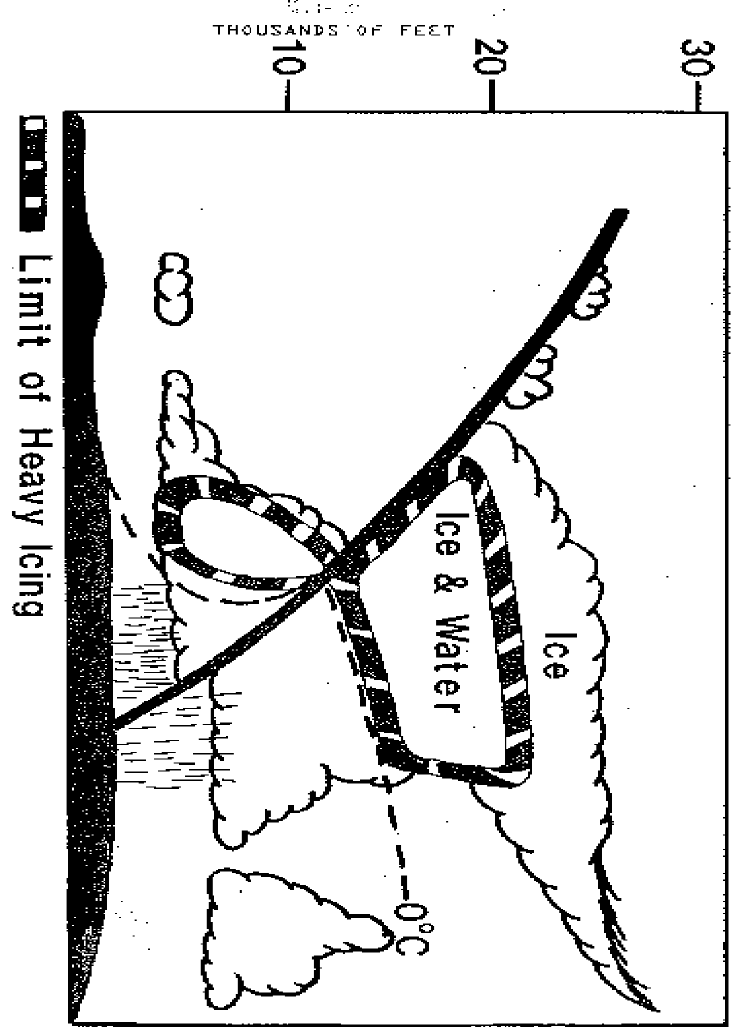


FIG. III-5 ICING ZONES ALONG COLD FRONT.

III-12

III-5 shows the limits of heavy icing associated with a cold front.

3. **Hail.** Hail on the surface occurs on an average of 2 to 3 times a year at the field; however, it is more prevalent in the adjacent mountains around Moffett Field. Two general synoptic storm situations may cause hail during the winter and spring months:

a. Cumulonimbus activity associated with a steep cold front moving rapidly moving down the California coast.

b. Unstable air (cPk) associated with a 'cold-core' low aloft over central California. If the temperature at the 500mb vortex is -25 degrees or colder, hail is likely in the vicinity. The cold core low aloft will cause area thunderstorm activity with associated hail, icing and moderate to severe turbulence. During the summer hail may occur with an air mass thunderstorm. When hail does occur in the Santa Clara Valley from the isolated air mass thunderstorm, it is generally light and of short duration.

4. **Turbulence.** Turbulence affecting aircraft ranges from a few annoying bumps to several jolts, which are capable of structural damage. Since turbulence is associated with many situations, a knowledge of its cause and behavior is helpful.

a. Low Level Turbulence. Whenever strong westerly through northerly winds occur aloft, low level turbulence exists in the San Francisco Bay Area. A good indicator is the gradient level winds from the Oakland sounding. If the 3000 foot winds are 25 knots or greater, from 270 through 360 degrees, expect moderate turbulence. The forecaster must be alert to brief these turbulent conditions to local flying club pilots.

Be alert for strong gusty northerly to easterly winds at stations to the east of Moffett Field and PIREPS of turbulence in the lower levels. (Santa Ana). Forecasts for occurrence at M.F.A. are very difficult as exact wind criteria must be met to place the field in a 'funnel'. As a general rule, do not forecast occurrence at M.F.A., but advise pilots of moderate turbulence. For flights in the local area, advise flying club members of easterly wind at small airports on the eastern side of the valley.

b. Clear-Air-Turbulence (CAT). A relatively steep gradient in wind velocity along a given line or direction (either vertical or horizontal) produces 'churning' motions (eddies) which result in turbulence. The greater the change in wind speed and/or direction, the more severe the turbulence. Turbulent flight conditions are frequently encountered in the vicinity of the jetstream where large shears in the horizontal and vertical are often found. Since this type of turbulence may occur in perfectly clear air with no visual clues in the form of clouds, the forecaster must pay particular attention to sudden changes either vertically or horizontally in the wind speed and/or direction in the upper levels (specially in the vicinity of the jetstream).

c. Mountain Wave Turbulence. Since most every flight which arrives or departs M.F.A. must fly over one or more of these mountain ranges, the forecasters must be alert for the formation of mountain waves in the proximity of the three major mountain ranges near the Bay Area. The three ranges are the Sierra Nevada, the Coastal range and the Cascades, which extend northward from Mount Larsen through Washington. When strong winds (50 knots or greater) blow approximately perpendicular to a mountain range, the resulting turbulence can be quite severe. Associated areas of steady updrafts and downdrafts may extend from 2 to 20 times the height of the mountain peaks. Under these conditions when air is stable, large waves tend to form on the lee side of the mountains and extend upward to the lower stratosphere and in a horizontal distance of up to 100 miles. Pilots have reported that the flow in these waves is remarkably smooth; other pilots have reported severe turbulence. As airflow moves up the windward side of the mountain range, the wind speed gradually increases, reaching a maximum near the peak of the range. After passing the peak, the flow breaks down into a complicated pattern with downdrafts predominating. See figure III-6 for airflow patterns and characteristic cloud forms associated with the mountain wave. Mountain waves will start to develop and are most pronounced when:

(1) The winds are within 30 degrees of the perpendicular to the mountain range with a speed of 25 knots or greater at the mountain top.
(2) the wind does not change direction with height.
(3) the wind speed increases with height.

As mentioned, wind speed and direction at the ridge level is critical for the development of the mountain wave. Wind information at the ridge level is available for the Sierra Nevada in the vicinity of Lake Tahoe. Instantaneous wind and temperature data is recorded and transmitted from Slide Mountain and Peavine every ten minutes. Slide mountain is located approximately 12 miles southwest of Reno Airport with sensors at 9650 feet M.S.L. Peavine is 9 miles northwest of the airport with sensors at 8266 feet M.S.L.. Reno's three hourly synoptic observations will include wind and temperature data for Peavine and Slide Mountain in the remarks section. Use of this data in conjunction with figure III-7 will aid the forecaster in determining the potential for mountain waves. In addition hourly surface weather observations for lee side reporting stations should be scanned carefully for column 13 entries on the observance of rotor and lenticular clouds. Good stations to watch are: Bishop (BIH), Reno (RNO), China Lake (NID), NAS Fallon (NFL), Blue Canyon (BLU), Lake Tahoe (TVL), Yakima (YKM) for the Cascade Mountains of Washington; and Redmond (RDM) for the southern end of the Cascade Mountain Range.

The forecaster should refer to COMNAVMETOCCOM 3140.4( ) for turbulence criteria tables and additional information in forecasting turbulence.

D. National Weather Service - San Francisco.

The local National Weather Service (NWS) forecast office is located at Monterey. This NWS is charged with civilian forecasting responsibilities in the Bay Area as well as marine and aviation interests from Washington to Southern California. Many NWS products are received locally via COMEDS. A bulletin of particular interest is the FZUS KSFO, providing a 48-hour

GENERAL WIND VELOCITY (KNOTS) AT LEVEL OF RIDGE

Height of Ridge above Windward Valleys (thousands of feet)	20	30	40	50	60	70	80	90	100
10	200	300	400	500	600	700	800	900	1000
9	180	270	360	450	540	630	720	810	900
8	160	240	320	400	480	560	640	720	800
7	140	210	280	350	420	490	560	630	700
6	120	180	240	300	360	420	480	540	600
5	100	150	200	250	300	350	400	450	500
4	50	120	160	200	240	250	320	360	400

Values less than 100	L I G H T
Values between 100 and 250	M O D E R A T E
Values between 250 and 500	S T R O N G
Values over 500	V E R Y S T R O N G

FIG. III-7 SUGGESTED CHART CRITICAL WAVE SPEED ASSOCIATED WITH DIFFERENT MOUNTAIN WAVE INTENSITIES IN THE SIERRA NEVADA.

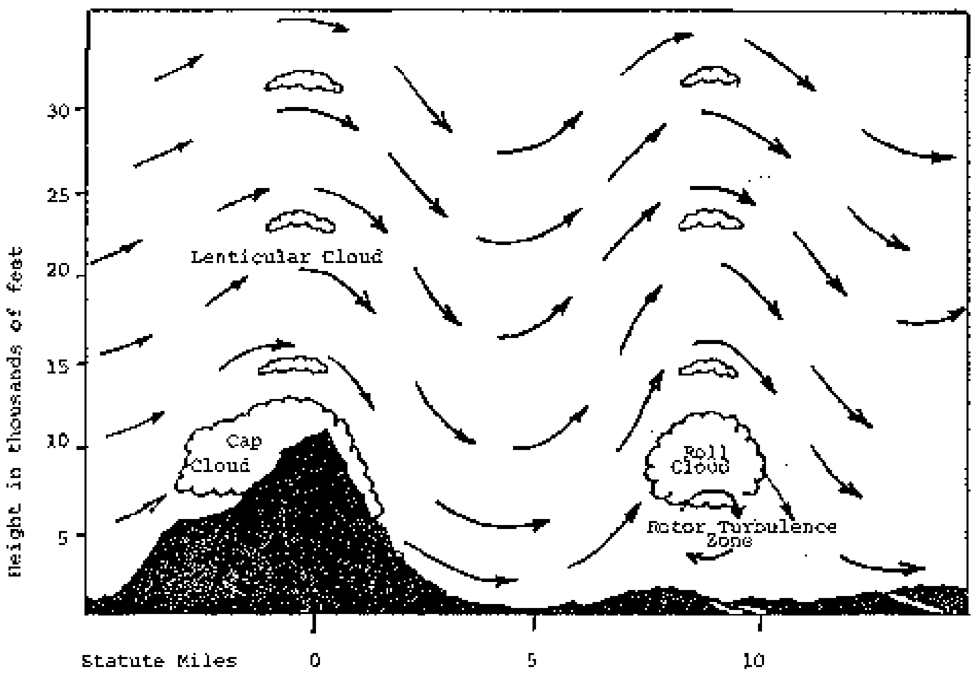


FIG. III-6 TYPICAL MOUNTAIN WAVE PATTERN AND ASSOCIATED CLOUDS.

forecast and warnings for the Bay Area and California coastal waters. It also includes synoptic reports from selected key reporting coastal stations. This advisory is issued every six hours commencing at 0830L.

Another useful aid is the NWS Marine Broadcast, transmitted from the forecast office of Monterey on a frequency of 162.40 MHz. This broadcast provides the same Bay Area and coastal waters forecast data that the FZUS KSFO, announces the issuance of new warnings, and provides synoptic observations in and around the Bay Area.

Forecasters are encouraged to utilize NWS products and to communicate directly with the NWS Forecast Office to ensure consistency in forecast and warning parameters.

E. Procedures for the Preparation, Revision and Verification of Routine Forecasts.

1. **Terminal Aerodrome Forecast (TAF**) is an encoded 24 hour forecast, issued two times daily at 15Z and 21Z. For explanation and breakdown of format, refer to NAVMETOCCOMINST 3143.1().

2. **Amendment Criteria**. The forecaster is responsible for ensuring an accurate forecast is available to customers. An amended TAF will be issued anytime the forecaster considers it advisable in the interest of safety, efficiency of aircraft operations, flight planning, dispatching, operational control and in-flight assistance to aircraft. For additional guidelines in determining when an amendment is required, refer to NAVMETOCCOMINST 3143.1.

3. **Verification.** TAF's are not verified from weather observations recorded on form MF-1-10 at this time, due to lack of certified observers and limitations of the ASOS described in section I-C. The forecaster on duty at Moffett Field must assume responsibility for the accuracy of the TAF, to include encoding for icing, turbulence and significant air temperature forecasts.

4. **Destructive Weather Warnings/Conditions**. NAVOCEANCOMFAC San Diego is responsible for issuing destructive and hazardous weather warnings/conditions when current weather or forecasted weather conditions are expected to meet the criteria as outlined in local policies. Warnings are not issued for M.F.A. specifically, but instead for the Bay Area as a whole. Again, the Moffett Field forecaster must assume responsibility for the safety of the local activities when micro-climate conditions differ from those forecast for the general area.

SECTION IV - SPECIALIZED FORECASTS

Support services tailored for specific operations are available on request. Support consists primarily of aviation and meteorological information, and forecasts for operational applications, climatological (statistical) information and information for long-range planning and design purposes. Requests should be forwarded IAW local policies. Requests should provide pertinent operational data (e.g. times, route or area of study, environmental parameters, point of contact, etc.). These services include but are not limited to, the following: (1) Optimum Path Aircraft Routing System (OPARS) and (2) climatological studies.

A. Optimum Path Aircraft Routing System (OPARS).

OPARS is a computerized pilot pre-flight planning aid and an environmental support product, and **DOES NOT** replace the required flight forecast (DD175-1). OPARS is available for many types and configurations of military aircraft. Various computer outputs are provided to enable the pilot/navigator to choose that which best suits their mission. Requests are made via OPARS 2.1 for windows with a minimum of two (2) hours notice. Order OPARS IAW local policy and the OPARS users manual.

B. Climatological Studies.

Climatology generally refers to the summation and/or study of the historical data. Normally, historical data are over 72 hours past time of the observation. In terms of our support, climatology represents oceanographic and meteorological data, which are not synoptically current. Climatological studies for a given area and time of the year is available by request. A minimum of one (1) week lead-time is required to properly prepare such studies. Requests should be forwarded by letter or memo to the NAR Santa Clara Weather office.
Reference materials and existing climatological studies are available on CD-ROM and in the technical library.

REFERENCES

1. Optimum Path Aircraft Routing System (OPARS) 2.1 for Windows User Manual

2. International Station Meteorological Climate Summary 4.0 (SEP 96)

SECTION V - ENVIRONMENTAL EFFECTS

This section will address natural environmental phenomena, which the forecaster must be aware of in order to provide optimum environmental services to supported commands at NAR Santa Clara. It is not the intent of this section to duplicate existing detailed instructions and publications on meteorological and oceanographic support, but rather provide supplementary information which assists the forecaster in understanding and properly addressing the specific requirements of supported commands.

A. *Moffett Federal Airfield Runway Conditions.*

1. **Selection of Duty Runway (IFR).** All military aircraft using M.F.A. Air Control are under Instrument Flight Rules (IFR) and positive control by the FAA through Bay Area Approach Control. All the airfields in the Bay Area must select runways which allow departing and arriving aircraft to fit smoothly into the flow of air traffic over the Bay Area. Thus, all aircraft over the Bay Area are flowing either northwest or southeast. The primary flow over the Bay Area is to the northwest. The southeast traffic flow over the Bay Area is normally selected during southerly wind situations.

2. **Runway Minimums**. The forecaster must refer to the latest IFR supplement, NATOPS manual and the Moffett Federal Airfield Air Operation's manual for detailed information. The following brief summary is presented for convenience:

	Condition
VFR	At least 1000 foot ceiling and 3SM visibility
IFR	Below 1000 foot ceiling **or** 3SM visibility

Precision Approach Radar (PAR)
Runways 14L, 14R, 32L at least 200 foot ceiling and 3\4SM visibility
Runway 32R at least 100 foot ceiling and 1\4SM visibility.

B. *Destructive Weather Warnings.* The NAR Santa Clara Weather Office is responsible for recommending conditions of readiness for hazardous or destructive weather conditions at M.F.A.. Recommendations are conveyed by telephone to the duty office for NAR Santa Clara, VR-55, VP-91, the ANG-129th and the flight services person at the air traffic control tower.

1. **Status of Fuel Pits During Thunderstorm Warnings**. Fuel pits remaining open or closed depends on the probability of lightning in the vicinity of the station. Under heavy weather conditions with embedded thunderstorms occurring within the local flying area, issuing Thunderstorm Condition 1 for extended periods of time must be accompanied by a recommendation concerning the status of the fuel pits. Forecasters will develop a recommendation based on radar, visual observance, strength of the system approaching, cell movement and present cell location in relation to the field.

2. **Wind Warnings.** To be effective, wind warning should be issued as far in advance as

possible. Particular reference is made to the protection of aircraft, the closing of hanger doors, and the security of loose gear that might constitute a missile hazard in high winds.

3. **NWS Aviation Severe Weather Bulletin(WW).** When one of these bulletins is issued for the local area, a condition of readiness commensurate with the bulletin must be issued by the forecaster. However, if the WW is not occurring or forecast as expected, and with approval of the Ops CPO, the forecaster may issue a lower condition/warning.

4. **Wind Chill and Heat Index Factor**. Although seldom requested, the forecaster should be aware that wind chill or heat index factors can have a significant effect on personnel engaged in outdoor activities. Personnel will have a wind chill problem during winter in cold water operations. Even during summer, wind swept fight decks in NOCAL OPAREAS are cold environments under the right conditions. See figure V-1 for the wind chill chart. Personnel engaged in SAR operations or field exercises in the inland areas during summer can be affected by heat index (apparent temperature). See figure V-2 for the heat index chart.

HEAT INDEX (HI) TABLE

Air Temperature (°F) and Relative Humidity Are Combined to Determine an Apparent Temperature or Heat Index (HI). An Air Temperature of 95°F with a Relative Humidity of 55 Percent Produces an Apparent Temperature (HI) of 110°F

Relative Humidity (%)

Air Temperature (°F)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
135	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
130	117	122	131	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
125	111	116	123	131	141	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
120	[illegible]	111	116	123	130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
115	103	107	111	115	[illegible]	[illegible]	135	[illegible]	151	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110	99	102	105	108	112	117	123	[illegible]	137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
105	95	97	100	102	[illegible]	109	113	[illegible]	123	129	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	91	[illegible]	95	97	[illegible]	101	[illegible]	107	110	115	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
95	87	88	90	91	[illegible]	[illegible]	[illegible]	[illegible]	101	104	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90	83	84	85	86	88	[illegible]	90	91	93	[illegible]	[illegible]	[illegible]	100	102	106	109	113	117	[illegible]	[illegible]	[illegible]
85	78	79	80	81	[illegible]	83	84	85	86	87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80	73	74	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75	[illegible]	69	70	71	72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	64	64	65	65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIG. V-2

SECTION VI - REFERENCES

1. Naval Meteorology and Oceanography Facility San Diego, CA
   Local Area Forecasters Handbook.

2. Naval Meteorology and Oceanography Detachment Lemoore, CA
   Local Area Forecasters Handbook.

3. Naval Meteorology and Oceanography Detachment Fallon, NV
   Local Area Forecasters Handbook.

4. Naval Meteorology and Oceanography Detachment Whidbey Is, WA
   Local Area Forecasters Handbook.

5. Summary of Meteorological Observations, Surface (SMOS), Moffett Field, CA
   Naval Meteorology and Oceanography Detachment Asheville, NC

6. International Station Meteorological Climate Summary
   Naval Meteorology and Oceanography Detachment Asheville, NC

7. Navy Oceanographic Data Distribution System (NODDS)
   FLENUMOCEANCENINST 3147.1

8. OPARS Users Manual
   FLENUMOCEANCENINST 3710.1

9. The use of the Skew-T, Log P Diagram in Analysis and Forecasting
   NAVAIR 50-1P-5

10. Aerodrome Forecast (TAF) Code
    NAVMETOCCOMINST 3143.1 series

11. Atmospheric Turbulence and Icing Criteria
    NAVOCEANCOMINST 3140.4 series

12. Pilot Weather Report (PIREP) Format
    Department of Transportation, FAA Note 7110.921

13. Procedures Governing Flight Weather Briefings and Preparing DD Form 175-1 and U.S. Navy Flight Forecast Folder, NAVOCEANCOMINST 3140.14 series

14. Meteorology Today, Fourth Edition
    C. Donald Ahrens

15. Satellite Imagery Interpretation for Forecasters
    Weather Service Forecasting Handbook No. 6, NOAA

16. Oceanography, Sixth Edition
M. Grant Gross

17. Contel Meteorologist Workstation (CMW) User Reference Manual Oracle Telecomputing Inc.

18. Marta Systems Super-86 Family (PCGRAFAX) Data Processing Software User Manual, Marta Systems Inc.